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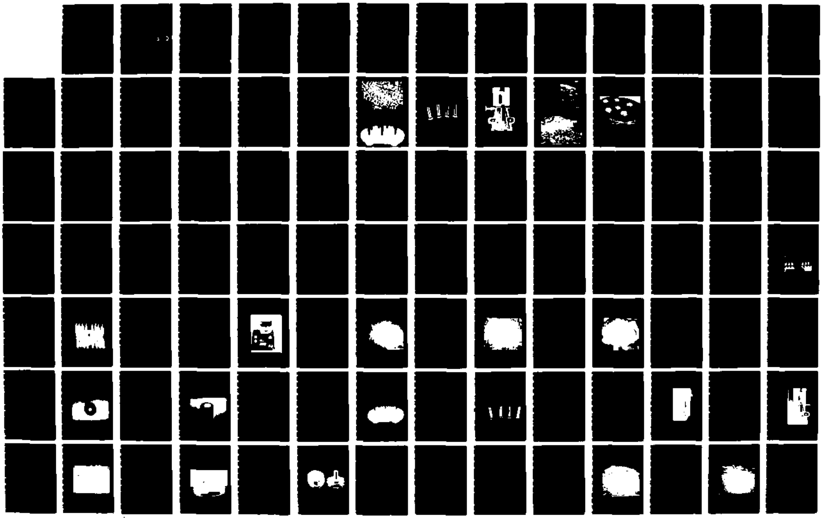

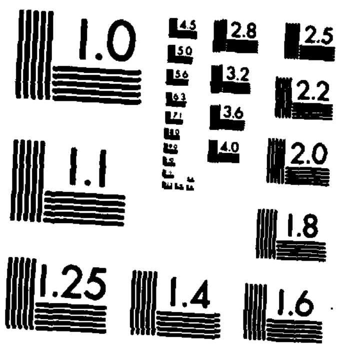

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INTRODUCTION

The retention of acrylic denture resins to metal based dentures and removable partial dentures has been accomplished using ~~utilizing~~ beads, nail heads, open ladders, or some other macroscopic retentive design.[1-3] Such retentive configurations may often encroach upon limited interarch space. Additionally, the adequacy of retentive strength found with these methods has been questioned by Dunny and King.[4] Yet, Brudvik[5] stated that, when sufficient in size and spacing, retention beads will provide an acceptable means for acrylic resin retention. Regardless, gaining the necessary clinical interarch space to use ~~utilize~~ this form of retention is not always possible.

An alternative to the macroscopic retentive designs has been reported by Garfield[6] in a technique for relining metal based dentures. This technique suggests the electrochemical etching of base metals, normally associated with metal-etched resin-bonded restorations, as a retentive system for denture acrylic resins.

This form of microscopic retention may provide an improvement over the disadvantages of interarch space and retentive bond strength reported with macroscopic designs. The retentive strength of composite resin materials to electrolytically etched base metals has been reported.[7-11] While these bond strengths have been high, the retentive strength of denture acrylic resin to electrochemically etched base metals has not been investigated. The purpose of this ~~investigation~~ was to examine the retentive bond strength of a denture acrylic resin to an electrochemically etched base metal in comparison to conventional

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THE TENSILE AND SHEAR BOND STRENGTHS OF POLY (METHYL METHACRYLATE) PROCESSED ON ELECTROLYTICALLY ETCHED TICONIUM

A

THESIS

Presented to the Faculty of

The University of Texas Graduate School of Biomedical Sciences

at San Antonio

in Partial Fullfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE

By

John Edward Zurasky, B.S., D.D.S.

San Antonio, Texas

May, 1986

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Improved adhesion of denture acrylic resins to base metal alloys

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INTRODUCTION

The retention of acrylic denture resins to metal based dentures and removable partial dentures has been accomplished utilizing beads, nail heads, open ladders, or some other macroscopic retentive design.[1-3] Such retentive configurations may often encroach upon limited interarch space. Additionally, the adequacy of retentive strength found with these methods has been questioned by Dunny and King.[4] Yet, Brudvik[5] stated that, when sufficient in size and spacing, retention beads will provide an acceptable means for acrylic resin retention. Regardless, gaining the necessary clinical interarch space to utilize this form of retention is not always possible.

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retentive beads.

METHODS AND MATERIALS

Forty nickel-chrome (Ticonium 100, Ticonium Co., Albany, NY) specimens 1cm square and 1.6mm thick were cast utilizing the manufacturer's directions for investment, burnout, and casting. Two groups of metal specimens were prepared: 20 for electrolytic etching and 20 with bead retention.

The specimens for electrolytic etching were recovered after casting, sandblasted, Ti-Lectro (Ticonium Co., Albany, NY) polished, and faced with 400 grit silicone carbide abrasive. Prior to etching with a Time Etch etching machine (Dental Laboratories, Inc., Baltimore, MD), they were cleaned by air abrading with 50u aluminum oxide and then steam cleaned. Electrical continuity was tested and the wire attached to the anode of the etcher with the metal specimens submerged in the acid.

Electrolytic etching was performed using 10% sulfuric acid with a current density of 300 milliamps for 3 minutes per metal square. An 18% hydrochloric acid was used in an ultrasonic unit for 10 minutes to clean the metal surface after etching. They were then rinsed with distilled water. A stereo microscope at 50X was used to assure that uniform etching of the specimens had been achieved. Photomicrographs of representative specimens were made using the Phillips model 505 scanning electron microscope (Phillips Co., Houston, TX). Figure 1 shows the resultant etch.

The bead retention specimens were prepared by placing six Kayon

(Kay See Dental Manufacture Co., Kansas City, MO) synthetic resin retention beads size 14, approximately 1.0mm in diameter, within a 5mm diameter circle in the center of the metal specimens. The beads were arranged so that the minimum space between any two beads was twice their diameter. The bead specimens were recovered after casting, sandblasted, and Ti-Lectro polished.

To facilitate fabrication of a wax pattern for acrylic resin processing, a teflon cylinder 3.5cm long was prepared with a 6.35mm diameter hole in the center. This cylinder was centered on the metal specimens and filled with melted baseplate wax (Hygenic Corp., Akron, OH) using a glass eyedropper. To prevent premature solidification of the wax, the metal specimens were warmed on a glass slab over a water bath at 200°F. Following sufficient cooling, the wax rod with the attached metal specimen was ejected from the teflon mold. Figure 2 shows the prepared specimens. Both the etched and the bead specimens were prepared for acrylic resin processing in this manner.

The specimens were flasked in a conventional upper denture flask (Hanau Engineering, Buffalo, NY). The flask was inverted and the metal specimens attached to the cap with a spot of sticky wax. Seven specimens were positioned around the periphery of the cap. The cope was placed on the cap and over the entire specimens. Dental stone was mixed and the cope filled so that the top of the wax rods were even with the top of the stone. Lastly, the drag was placed in position without the center plug and filled with dental stone to complete the modified flasking process.

After setting, the flasks were placed in boiling water. The wax was boiled out and wax solvent was used to remove the residue. Soap was used to remove any oily film from the wax solvent and the flasks were allowed to cool. Alcote separating agent (L.D. Caulk Co., Milford, DE) was painted on the stone surfaces. Lucitone 199 (L.D. Caulk Co., Milford, DE) was mixed according to the manufacturer's directions. The specimens were packed similar to dentures; three trial packs were done utilizing 3000 psi pressure. The resin was cured for nine hours at 163°F in a Hanau (Hanau Engineering, Buffalo, NY) curing unit. The specimens were recovered, shell blasted, and stored in distilled water at 20°C for 17 days prior to bond testing. Figure 3 shows the completed specimens.

Tensile bond strengths of the specimens were determined using the Instron Universal Testing Machine (Instron Corp., Canton, MA) with a 50 kilonewton load cell. The metal tabs were positioned in a holding device on the upper arm of the Instron, and self aligning "V"-grips were used to grasp the acrylic resin rod from the lower arm (Figure 4).

The chart paper speed was set at 50mm/min with a 1000 newton full scale. The crosshead speed for the Instron was set at 5mm/min. The force in newtons required to separate the acrylic resin rods from the metal specimens was recorded as the tensile bond strength.

A Scanning Electron Microscope was used to evaluate the fracture site of the etched and the bead specimens. Representative specimens for the two retentive techniques were examined and evaluated as to their fracture mode.

The resulting tensile bond strengths were subjected to a Students' T-test to determine if significant differences in bond strengths were observed.

RESULTS

The results of the tensile bond strengths for the etched and the bead specimens are shown in Table 1. The mean tensile bond strength for the etched specimens was 472.5 newtons (16.70 MPa) with a standard deviation of 130.1 (4.60 MPa). The mean tensile bond strength for the bead specimens was 134.9 newtons (4.77 MPa) with a standard deviation of 75.7 (2.68 MPa).

Statistical analysis using the Students' T-test revealed that the tensile etched bond strengths were significantly ($p < 0.001$) higher than the tensile bead strengths.

Examination of the fracture sites using the scanning electron microscope demonstrated that a cohesive failure occurred commonly in the poly methyl methacrylate leaving acrylic resin fragments mechanically locked into the etched metal specimens (Figure 5). At times metal particles were also observed imbedded in the fractured acrylic resin surfaces.

Examination of the bead specimens showed that an adhesive failure occurred between the acrylic resin and the beads. Extensive plastic deformation of the poly methyl methacrylate was evident (Figure 6).

DISCUSSION

Fabrication and preparation of the test specimens were accomplished utilizing laboratory methods that are commonly used for clinical prostheses. These same laboratory procedures would be used for clinical application of the results of this study.

The poly methyl methacrylate rod was waxed-up directly on the etched surface of the metal. The etched surface was fully contaminated with wax, wax solvent and soap, then flushed with clean boiling water and allowed to dry before the acrylic resin was split-packed.

The effect of any manipulation or contamination of the etched metal surface has not been studied in depth. It has been reported by McLaughlin[7,8,12] and Thompson and Livaditis[11] that the etched surface of the metal must be maintained contamination free to preserve the bonding capability. This study gives indications that manipulation and contamination may not be as critical as was originally thought. Some consideration must be given to the packing conditions of 3000 psi applied pressure which cannot be directly compared to resins placed intraorally. Meiers et al.[13] looked at a variety of surface treatments on the bond strength of etched metal retainers. They found that abrasion with salivary contamination did not decrease the shear bond strength, and that the etched metal surface may not be as fragile as is thought. It is evident that further research is necessary in this area.

It should be emphasized that controlling the etching conditions is one of the most important factors in consistent etching.[8,12,14-19] Using controlled times and currents with precisely measured acids, one

can expect to routinely obtain retentive etch patterns.

It is apparent that a very strong mechanical bond is available between the etched metal base or removable partial denture framework and the acrylic resin. The clinical applicability of these findings can be utilized on a base metal prosthesis where retention of acrylic resin is necessary. This retention capability can salvage an ill-fitting metal based denture by allowing a reline of the intaglio surface. The acrylic resin will bond to the metal over the entire etched surface area.

Acrylic resin retention has always been a problem where interarch space is minimal. Microscopic etched retention preserves the maximum remaining space for placement of artificial teeth.

CONCLUSIONS

The following results of this study show that the tensile bond strength using electrochemical etching to obtain microscopic retention of the poly methyl methacrylate is significantly greater than the acceptable bead retention:

1. The etched tensile bond is nearly 3.5 times the strength of the bond with beads.
2. The tensile fracture for the etched specimens was one of a cohesive failure of the acrylic resin. The bead specimens failed adhesively at the resin-metal interface.

Table 1. Tensile Bond Strengths of Etched and Bead Specimens

Technique	N	Mean Bond	S.D.
Etched	20	16.70 MPa	4.60 MPa
Beads	20	4.77 MPa	2.68 MPa

$P < 0.001$

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LEGEND SHEET

Figure 1. Photomicrograph of electrolytically etched nickel-chrome alloy (200X).

Figure 2. Wax rods on metal specimens being prepared for acrylic resin processing.

Figure 3. Specimens as prepared for tensile bond testing.

Figure 4. Specimen in place in upper holding device and lower "V" grips of the Instron Machine.

Figure 5a. Tensile fractured etched specimen: lower one-third of photomicrograph shows the etched metal surface outside of the acrylic resin rod. Upper two-thirds shows acrylic resin retained in the etch (45X).

Figure 5b. Fractured specimen showing cohesive failure with large block of acrylic resin remaining attached to the etched metal (50X).

Figure 6. Adhesive failure and plastic deformation of the acrylic resin retained by beads.

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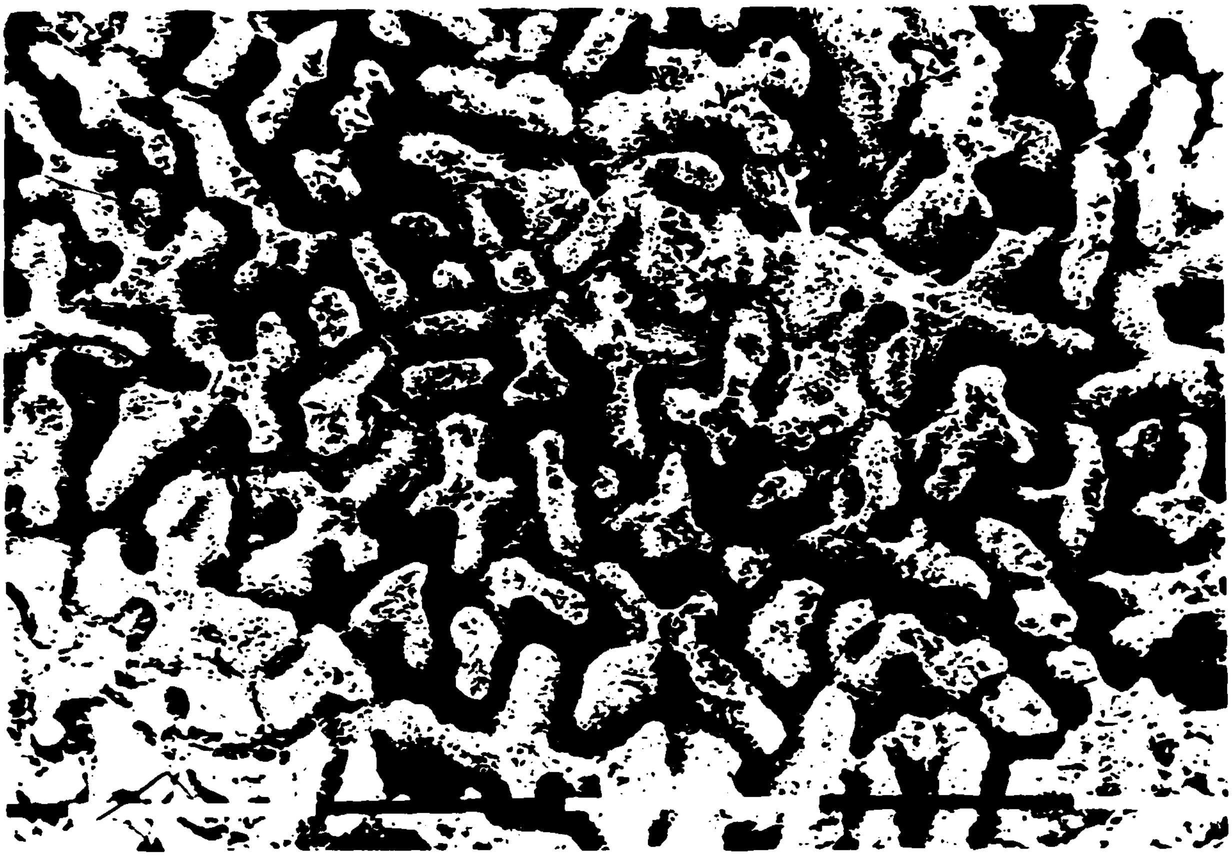

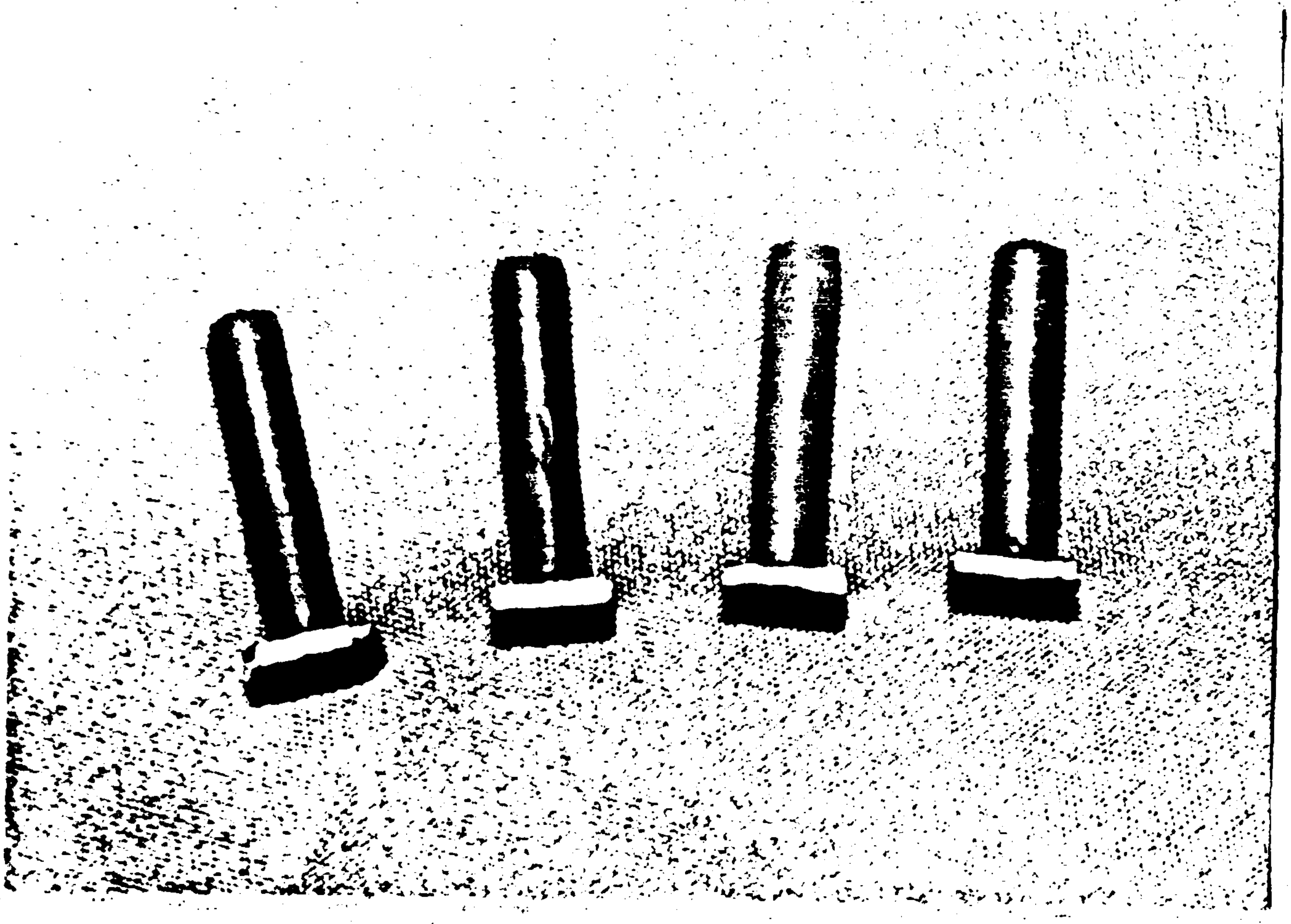

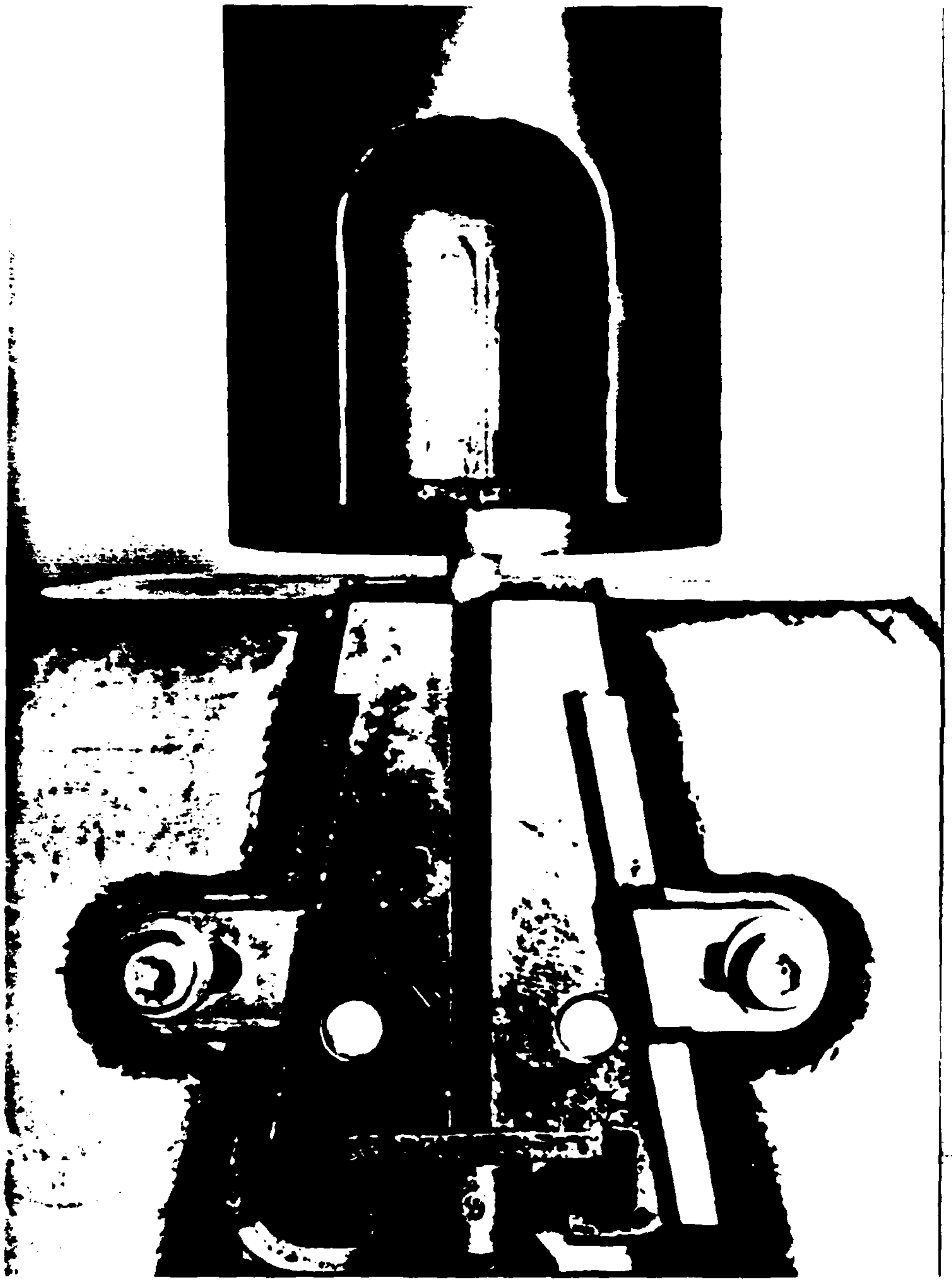

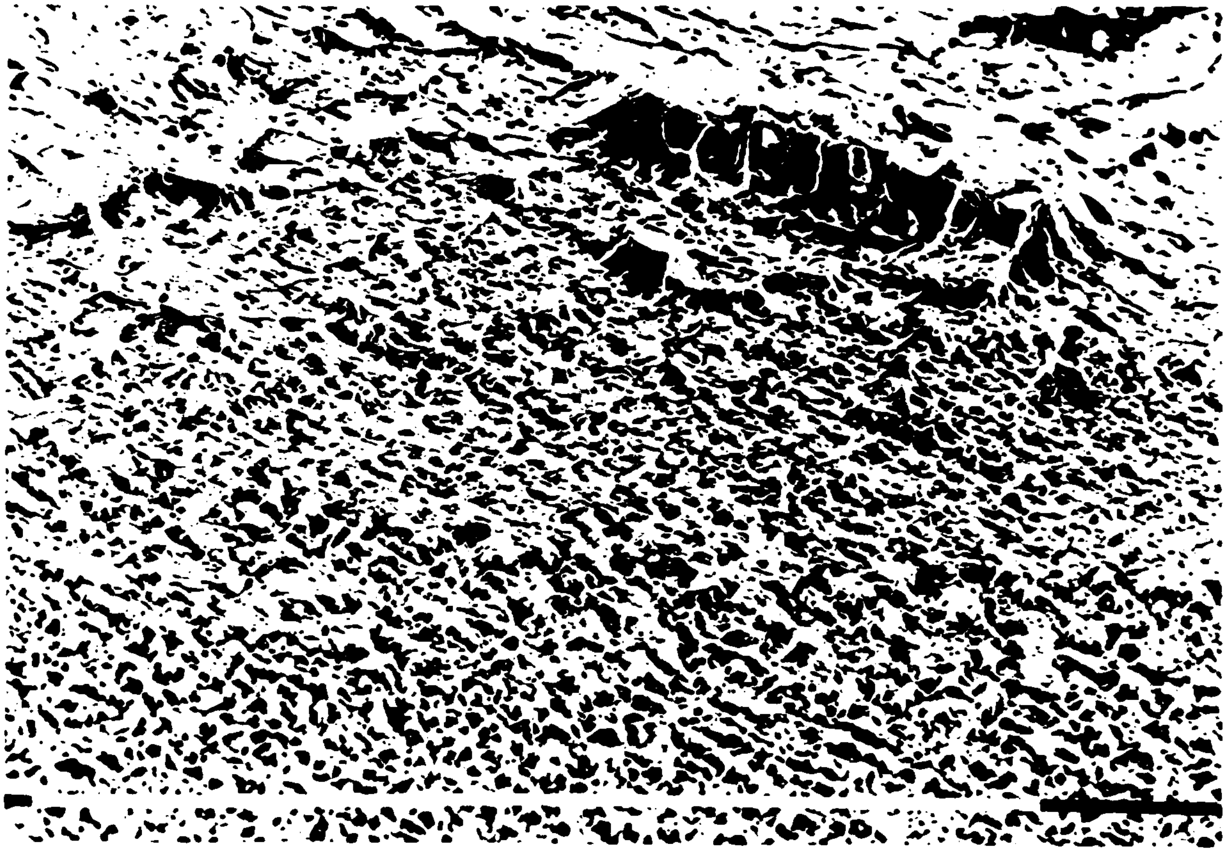

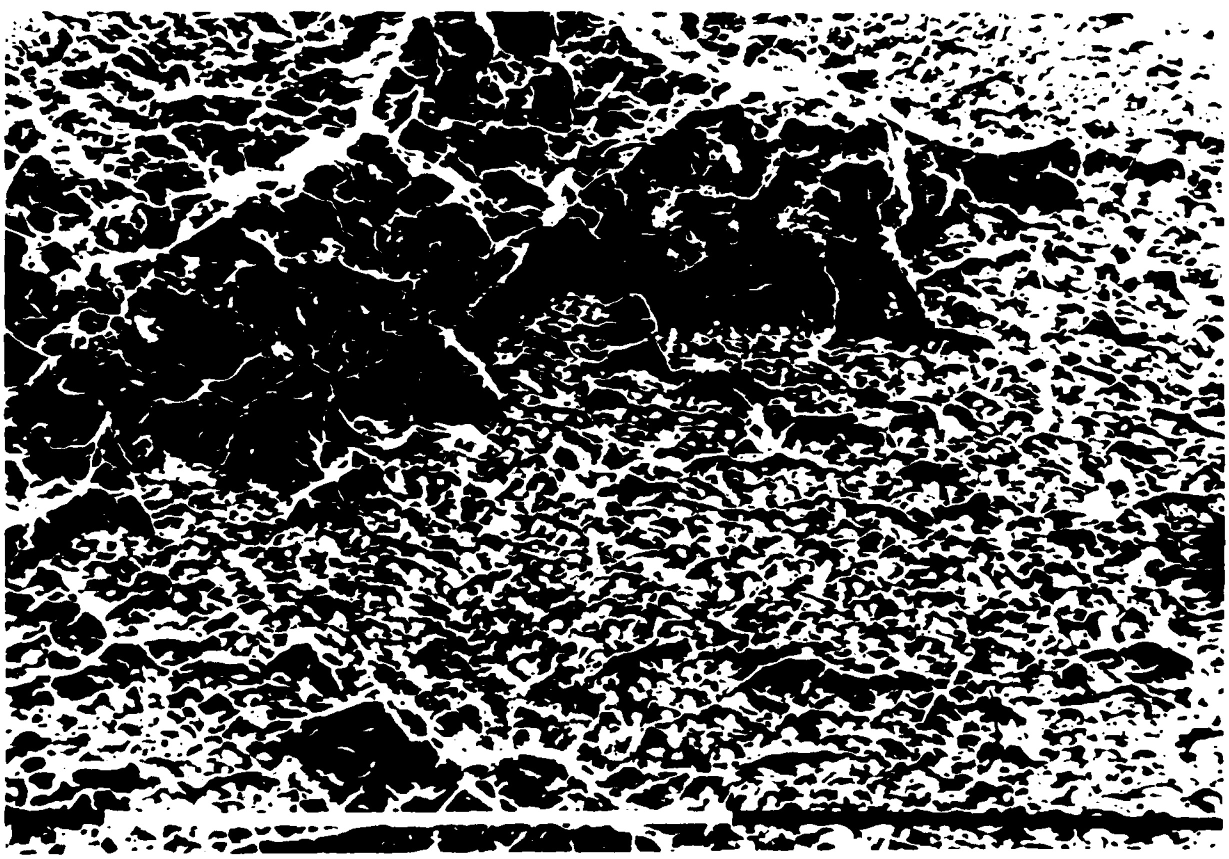

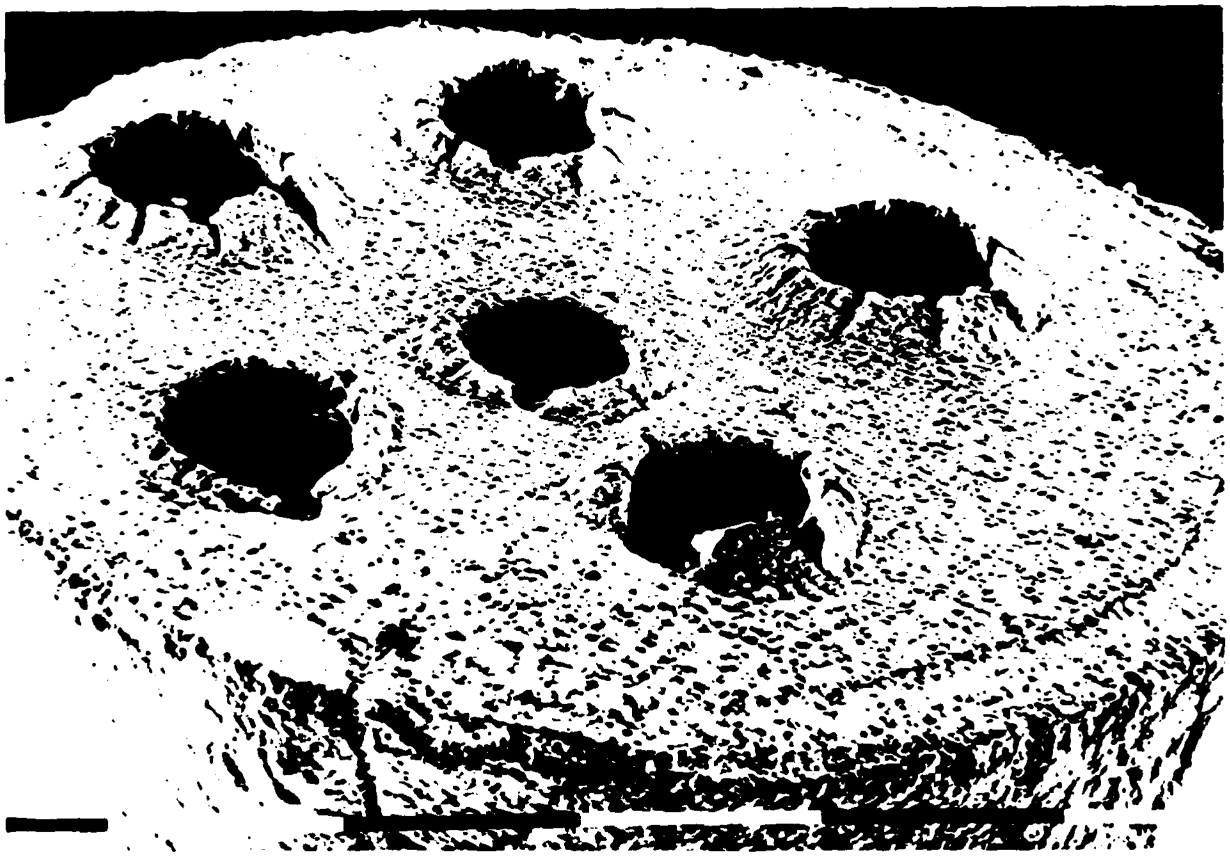

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THE TENSILE AND SHEAR BOND STRENGTHS OF POLY (METHYL METHACRYLATE) PROCESSED ON ~~ACID~~ ELECTROLYTICALLY ETCHED TICONIUM

John Edward Zurasky

APPROVED:

Supervising Professor

5 May 1986
Date

APPROVED:

Terry M. Mikiten, Ph.D.
Associate Dean

DEDICATION

I dedicate this thesis to my wife, Nancy, and to my son, Jacob. It was with their patience, understanding, and support that I was able to attain this goal.

I also dedicate this thesis to my parents, John and Elizabeth Zurasky. From my earliest memories they taught me that "good enough" was not the answer. To attain the unattainable goals one must do the "best" he can do with no regrets.

I am thankful for the way I was raised and for the motivation my family instilled in me. To you I dedicate this thesis.

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THE TENSILE AND SHEAR BOND STRENGTHS OF POLY (METHYL METHACRYLATE) PROCESSED ON ELECTROLYTICALLY ETCHED TICONIUM

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The electrochemical etching of dental alloys has been incorporated into numerous restorative techniques. The bonding of resin materials to etched alloys is reported with acid etched retainers, resin veneers, and proposed for relining metal based dentures.

The difficulty in relining metal based dentures has been a primary disadvantage associated with their use. The ability to retain denture acrylic resins by electrochemical

etching may facilitate relining procedures. Additionally, an improvement in acrylic resin retention may be found over conventional retention techniques.

The purpose of this research is to examine the bond of poly (methyl methacrylate) to electrolytically etched Ticonium and to quantitatively measure the tensile and shear bond strengths in comparison to the accepted retention of poly (methyl methacrylate) to Ticonium with beads.

Eighty nickel-chrome alloy (Ticonium 100) specimens, one centimeter square and 1.6 millimeters thick were cast. Forty specimens were prepared with bead retention and the other 40 were electrolytically etched. A rod of poly (methyl methacrylate) 3cm long and 6.35mm in diameter was processed onto the Ticonium specimens using the conventional pressure pack, heat cure technique.

An Instron Universal Testing Machine was used to quanitatively measure the tensile and shear bond strengths. A scanning electron microscope was used to examine representative electrolytically etched Ticonium specimens and to evaluate the fracture site.

The tensile bond strengths were significantly higher ($p < .001$) for the electrolytically etched specimens as compared to the specimens with beads. The more commonly used shear bond testing for evaluating resin bond strength to etched metals was found inappropriate in this study, due to the high plastic behavior of the acrylic resin under load.

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I. INTRODUCTION

To date, macroscopic retention has been used for the attachment of denture acrylic resins to metal frameworks. This mechanical retention, be it nailheads, beads, open ladder, or spurs, requires significant space, either interarch space or on the tissue surface of a metal based denture that needs relining. In fact, this is one of the reasons metal based dentures are not used more often, even though they have some advantages over acrylic resin bases.

The electrolytic etching of alloys has been shown to be of significant value in dentistry for the purpose of bonding resin based materials. This technique may allow for sufficient retention of denture acrylic resin to metal based dentures and removable partial denture frameworks to make relines feasible and improve framework design.

Metal electrolytic etching offers a new approach to obtain retention of denture acrylic resin to metal. This retention method would be the mechanical interlocking of acrylic resin molecules into the microscopic undercuts in the metal surface of denture frameworks in place of conventional retention methods that require significant space. Limited interarch space could be preserved for placement of teeth and metal based dentures could be relined with ease.

Metal based dentures have many advantages but up to now, a major disadvantage has limited their use. This

problem has been caused by the difficulty, almost impossibility, to adequately and economically reline them. Using etching of the metal base as the retention mechanism for the denture acrylic resin, refitting can now be simplified.

This form of microscopic retention may be an improvement over the macroscopic retention designs. All the remaining interarch space can be used for placement of artifical teeth and the bond strength may be higher due the interlocking along the entire etched surface area. The retentive strengths of composite resin materials to electrolytically etched base metals have been reported. While these bond strengths have been high, the retentive strength of denture acrylic resin to electrolytically etched base metals has not been investigated. The poly (methyl methacrylate)-etched metal bond needs to be evaluated and quantified.

This reasearch examines the mechanical bonding of denture acrylic resin to electrolytically etched Ticonium (Ticonium Co, Albany, N.Y.) utilizing tensile and shear bond strengths measured on an Instron Universal Testing Machine (Instron Corp., Canton, Mass.) and comparing the results to the bond strength of Ticonium with bead retention.

II. LITERATURE REVIEW

A. Acid Etching

Buonocore (1955) studied the effect of acid treatment on enamel for the purpose of increasing adherence of restorative materials. He found that by treating enamel with phosphoric acid, there was a significant increase in the surface area and the surface wettability for more intimate contact between the acrylic resin and enamel thereby increasing adhesion.

Rochette (1973) described the attachment of a splint to enamel by using a gold framework with undercut perforations bonded to acid etched enamel. He is given credit for introducing the acid-etch metal retainers to dentistry. Since then many authors including: Stuart (1974), Stolpa (1975), Lambert et al.(1976), Kochavi et al.(1977), Jenkins (1978), Reinhardt et al.(1979), Sweeney et al. (1980), Esposito (1981), Yanover et al.(1982), and Hamada et al.(1985), have contributed articles on this subject.

Howe and Denehy (1977) used a technique of acid etching enamel and bonding with a composite resin for replacement of a missing anterior tooth. A ceramo-metal nonprecious framework was constructed with retentive holes for the resin. Jordon et al.(1978) evaluated 86 temporary fixed partial dentures of the acid-etch resin technique. The acid etching produces microporosities up to 50 microns deep that

fill with the resin resulting in an interlocking action of the resin projections in the microporosities.

Nathanson and Moin (1980) modified Howe and Denehy's (1977) design using rectangular perforated metal pads used in orthodontics instead of a cast framework. This has the advantage of being a one appointment technique.

Livaditis (1980) described cast resin-bonded retainers for posterior teeth, including design, fabrication, and bonding. He feels that these retainers are an alternative to the accepted fixed retainer.

Williams et al.(1982) studied retainer design and found that most retainer failures occurred at the retainer - composite resin interface. With greater occlusal forces being placed on these restorations, failures were more common at the composite-metal interface than the enamel-composite area. Progress necessitated a stronger bond to the metal.

Dunn and Reisbick (1976) described and used an electrochemical etching of Vitallium to obtain a mechanical bond of ceramic coatings. They found that complex geometric patterns on the surface of the metal increased the surface area and the retention sites. Tanaka et al.(1979) developed a technique for retention of resin veneers on complete crowns by using a pitting corrosion of the nickel-chromium copper alloy.

McLaughlin (1981) wrote of the etched metal retainer. The metal framework was electrolytically etched using

sulfuric acid and then cleaned using hydrochloric acid to remove the surface layer of impurities. The etched surface was found to be microscopically roughened thereby providing mechanically retentive locks for the resin. He specified that the etch must not be contaminated and that contamination would occur if the wax protecting the nonetched areas was boiled off. McLaughlin (1982) stated that the composite-metal bond using metal etching is two times as strong as the enamel-composite bond. He again cautioned that the etched metal surface is fragile and must be protected from contamination. The etched surface should not be touched as even the oil from the fingers will disturb the bonding capability.

Livaditis and Thompson (1982) found the tensile bond strength of resin to enamel to be 8.5 - 9.9 MPa (1200-1400 psi), the cohesive bond of the composite resin, 33 - 60 MPa (4800-8700 psi), and the resin to etched metal 27.3 MPa (3960 psi). Thompson and Livaditis (1982) found similar bond strengths and stated that the weakest bond is now that of resin to enamel. They also stated that contamination of the etched surface must be avoided. McLaughlin and Foerth (1982) found that by electrolytically etching the metal, the entire surface becomes microscopically retentive.

Simonsen et al.(1983) described the electrolytic etching process. A low voltage direct current is passed through the electrolytic solution by way of a stainless steel cathode. The metal casting functions as the anode.

A specific current density and time are used to obtain a controlled etch. The casting is then cleaned with acid in an ultrasonic unit.

McLaughlin (1982) described a one-step etching process with the benefit of reduced etching time by mixing acids and etching in an ultrasonic unit. A follow-up article by McLaughlin and Masek (1985) compared bond strengths using the one and two-step etching. They found no significant difference between the etch systems.

This electrolyically etched retention has been shown to produce very high bond strengths with composite resin (Thompson et al. 1981 and Dhillon et al. 1983). The bond strength is reported to be dependent on a number of variables including: the type of metal alloy, the specific etching conditions; type of acid, time, and current, and the surface area to be etched. Thompson (1982) worked out the best etching conditions for a variety of non-precious alloys. Thompson et al.(1984) and Jensson et al.(1985) studied other alloys for etch capability. Del Castillo and Thompson (1982) investigated some laboratory variables with respect to resulting bond strengths. Al-Shammary et al.(1983) studied the effect of etching times upon the bond strength. Sloan et al.(1983) examined the bond strength of resin to etched metal specimens provided from different laboratories. They found that the quality of etch and the bond strength varies greatly from one lab to another.

Meiers et al.(1983) studied the effect of surface

abrasion and salivary contamination on the etched metals and found no significant decrease in resin bond strength.

Garfield (1984) described a technique for relining metal based dentures using metal acid etching. He claimed that the acid etching will cause an adherence of the acrylic resin to the metal base using routine laboratory reline procedures. He did not present any data to substantiate this claim.

B. Methyl Methacrylate

Acrylic resin has been in use for denture bases since 1937, and has become the material of choice (Vernon and Vernon, 1941). Pryor (1943) stated at that time, methyl methacrylate was the best all around plastic for dentures available to the profession. Woelfel (1971) estimated that more than 95% of all complete denture bases were constructed of methyl methacrylate polymers or copolymers. Sweeney et al.(1942) wrote of the dimensional problems with acrylic resins; the shrinkage during processing, and the expansion which occurs as a result of water absorption. Further studies by Skinner and Cooper (1943), Smith (1961, 1962), Chevitarese et al.(1962), and FitzRoy et al.(1963) evaluated the dimensional changes of denture acrylic resins.

Brauer (1966) and Voger (1974) described the composition and reaction of methyl methacrylate. It is the product of acetone combining with hydrogen cyanide in the presence of methyl alcohol and sulfuric acid. The monomer,

methyl methacrylate, is supplied as a liquid with an inhibitor, usually hydroquinone, and a crosslinking agent such as ethylene dimethacrylate. When combined with the polymer powder, which contains benzoyl peroxide as an initator, the reaction forms the acrylic resin, poly(methyl methacrylate). Stafford et al.(1982) wrote that the strength of poly (methyl methacrylate) should be suspect due to three-quarters of a million dentures repairs costing nearly $750,000 annualy as reported by the National Health Service of England and Wales. Kelly (1969) stated that fracture of the denture is very common and occurs mostly as fatigue failure caused by repeated flexure. Johnson et al. (1981) confirmed this and modified the flexure fatigue testing to a two-way test for accurate measurement. Cornell et al.(1960) found that crosslinking the monomer with 10-20% ethylene dimethacrylate notably improved the impact resistance.

Tensile strength has been suggested to be one of the important properties that directly affects clinical fracture. Matthews and Wain (1956) showed that fracture of the denture base was the result of tensile failure of the material. Smith (1961) stated that the pigmentation in poly (methyl methacrylate) decreased tensile strength due to the introduction of flaws in the material.

Smith (1961) and Stafford and Smith (1968) found a reduction in tensile strength after water absorption. They attributed this lower tensile strength to the plasticizing

action of the water. Cornell et al.(1960) showed a decrease in impact strength when acrylic resin samples were stored in water. Stafford and Braden (1968), Hargreaves (1978), and Barsby and Braden (1979) studied the water sorption properties and the effect on the acrylic resin. Peyton and Mann (1942), and Skinner and Cooper (1943) showed that water absorption partially compensated for the shrinkage during polymerization. Braden (1964) found that maximum water absorption for an average denture may required up to 17 days at room temperature, depending on the thickness of the acrylic resin and the diffusion coefficient. He also found that at oral temperature the water absorption was two times faster. Brauer and Sweeney (1955) found that water absorption and molecular weight of the polymer related inversely. As the molecular weight was increased, the water absorption decreased. The ADA Specification No. 12 states, "the increase in weight of the polymer shall not be more than 0.7 mg/cm sq. of surface after immersion in water for 24 hours at 37.1 degrees C".

C. Metal Based Dentures

Metal based dentures were swaged until Taggart developed a casting process (Pryor, 1928). Dootz (1980) described the procedures for fabrication of non-precious metal base dentures. The laboratory phases are described in detail from duplication of the master cast to finishing of the casting.

Faber (1957) listed the advantages of a cast metal base denture including:

1. Less lateral deformation in function
2. Better thermal conduction
3. Less tissue change
4. Less porosity, less resorption
5. More accurate
6. Patients master the use of dentures faster
7. Treatment of poor ridges seem more successful
8. Attains a snugness of fit.

Moore (1967) also listed these advantages of metal based dentures and stated that their combination aid in the maintenance of the health of the denture supporting tissues.

A review of some of the above points citing investigations by various authors will be discussed.

1. <u>Less lateral deformation in function</u> - Regli and Kydd (1953) and Regli and Gaskill (1954) showed that deformation during mastication was 8.5 times less with metal base dentures than those constructed with acrylic resin. They found that the mandibular acrylic resin denture may deform up to five millimeters during function. Lambretch and Kydd (1962) also found deformation of the maxillary acrylic resin denture causing it to move one and a half millimeters away from the palate. Sweeney (1958) stated that acrylic resin has been the most accepted denture base material since

its introduction in 1937. One reported problem is the low fatigue strength which can lead to breakage. Kelly (1967) stated that flexure fatigue is the chief cause of failure with poly (methyl methacrylate). He stated that a solution to problem cases is the metal base. Smith (1961) suggested that flexing during mastication can lead to fatigue failure. Johnson and Mathews (1949) estimated that complete dentures flex about 500,000 times a year. Kelly (1969) showed that the frenum notch, debris, impurities, or scratches can act as stress concentrators leading to flexure fatigue.

2. Metal is a better thermal conductor than acrylic resin - Campbell (1935, 1936) felt that an aluminum based denture was best because the thermal conduction allowed stimulation of oral tissues and helped to maintain tissue health. On the other hand, Kapur and Fischer (1981) found that increased palatal tissue temperatures under metal bases interfered with the gustatory response to taste more than acrylic resin bases.

3. Less tissue change will occur - Barsoum, Eder, and Asgar (1968) stated that because a better fit could be obtained, the metal based denture would be less irritating to the tissue. Woelfel and Paffenbarger (1959) showed that 0.5mm shrinkage across the palate still resulted in a clinically acceptable fit. They stated that the tissue adapts to the gradual

distortional changes.

4. Less porosity with a metal base resulting in less resorption - Lang (1974) stated that the potential for plaque adherence causing tissue irritation and inflammation was less with a metal base.

5. The metal base is more accurate - Lundquist (1963) showed that due to the taper of the ridges, there was an average discrepancy of 0.02 inch for heat-cured resin bases as compared to 0.0015 inch for an aluminum casting in the palatal area. Woelfel and Paffenbarger (1960) found dimensional changes of 0.02-0.22% and Mowery et al.(1958) found up to 0.2mm dimensional change with no significant effect on fit of the denture. Yet, Anthony and Peyton (1962) found that a cast chrome-cobalt alloy had only the same accuracy of fit as the best heat-cured dentures. Also, Woelfel and Paffenbarger (1961) stated that a metal base will not necessarily fit the cast better than acrylic resin base.

Many investigators studied the self-curing resins with the hope of obtaining a better fit. Caul et al.(1952), Mirza (1961), Shepard (1968), Kraut (1971), and Winkler (1972) found that the final product was as good as heat-cured dentures. Civjan et al.(1972) and Weaver and Ryge (1971) stated that their findings indicated clinically acceptable results using self-curing resins with the benefit of considerable time savings.

Grunewald (1964) felt that gold was the metal of choice for metal based dentures. His study showed that the average weight loss through extractions and resorption on the mandible was 29 dwt and 23 grains. To replace this, the metal base needed to weigh between 14 and 16 dwt. He thought that this weight was necessary for normal muscle function and to maintain vertical dimension. Lang (1974) also described the use of gold in the mandibular denture to satisfy the advantages previously listed.

The use of aluminum denture bases was favored by Sizeland-Coe (1951), Campbell (1953, 1954), Lundquist (1963), Barsoum et al.(1968), and Swartz (1966). Swartz (1966) found that aluminum bases were the most resistant to vertical dislodgement. White et al.(1985) found that anodized aluminum resisted corrosion better than nonanodized. Tregarthen (1949) also recommended anodizing to increase corrosion resistance.

Defurio and Gehl (1970) examined retention of maxillary dentures with respect to the type of base. Aluminum, chrome-cobalt, gold, and acrylic resin bases were compared. They found that the chrome-cobalt resisted vertical displacement the most, followed by aluminum, acrylic resin, then gold. Swartz (1966) showed that an aluminum base had the best retention and had better wettability than acrylic resin. Halperin (1980) recommended long term clinical follow-up studies to evaluate the aluminum based dentures.

Metal based dentures have very few reported

disadvantages. They are contraindicated for patients that have severe undercuts or are hypersensitive to specific metals. The greatest disadvantage is the difficulty in refitting or relining. This has limited their use to the very mature, well healed ridges (Lang 1974).

Brauer et al.(1959), Shaffer and Filler (1971), and Christensen (1971) wrote on relining techniques in general. Lang (1974) stated that the problem with gold based dentures is that they cannot be relined. Grunewald (1964) recommended a satisfactory reline by cutting back the gold base to allow one millimeter of acrylic resin thickness. There would be no bond of the resin to the base. Faber (1957) listed the cost and the difficulty of refitting as disadvantages of metal bases. Sherman and Komorech (1985) presented a technique for refitting a metal based denture. Their technique involved removing one millimeter of metal from the tissue surface then refabrication of a new metal base to be processed onto the existing teeth.

D. Acrylic Resin Retention

Acrylic resin retention to metal bases or metal frameworks has been only minimally addressed in the literature. Dunny and King (1975) looked at different retention designs with respect to retention strength of acrylic resin to metal frameworks. They found that beads or nailheads do not provide strong attachment of the resin to the framework. Bulk of resin for strength was the most

important factor. Brudvik in Morrow, Rudd, and Eissman's Dental Laboratory Procedures, (1980), stated that retentive beads, size 14, placed so that there is space between them equal to twice their diameter will provide excellent acrylic resin retention.

E. Summary

Electrolytically etched retention of denture acrylic resin may provide an improvement over the disadvantages of inadequate interarch space and retentive bond strength reported with macroscopic designs. The retentive strength of composite resin materials to electrolytically etched base metals has been reported. While these bond strengths have been high, the retentive strength of denture acrylic resin to electrolytically etched base metals has not been investigated. The use of metal base dentures could be facilitated if a bond between the acrylic resin and the metal was attained and a better technique developed for relining when necessary. With the advent of metal etching, this may now be possible.

The purpose of this research is to quantify the bond between poly (methyl methacrylate) and electrolytically etched Ticonium by measuring the tensile and shear bond strengths. A comparison with bead retention will be used to give clinical relevance.

F. Problem Statement

The difficulty in relining metal based dentures with respect to acrylic resin retention has limited their use.

Electrochemical etching may provide improved retention of denture acrylic resin to metal based dentures for enhanced reline capability and to removable partial denture frameworks to maximize remaining interarch space.

Hypothesis:

An acceptable bond can be attained between acrylic resin and electrolytically etched Ticonium *.

Null Hypothesis:

There is no usable bond between acrylic resin and electrolytically etched Ticonium *.

* Ticonium Co., Albany, N.Y.

III. RESEARCH OBJECTIVES

The objectives of this project were to:

1. Evaluate the possible bond that could be obtained by electrolytically etching alloys used for metal based dentures or removable partial dentures to poly (methyl methacrylate) as compared to the retention obtained with beads.

2. Examine a potential method to nullify the greatest problem with metal base dentures, that of the difficulty to reline them.

3. Propose a retentive mechanism for poly (methyl methacrylate) on base metal alloys to maximize remaining space and bonding capability.

IV. MATERIALS AND METHOD

A. Preparation Of The Ticonium Specimens

Plastic patterns 1cm square and 1.6mm thick were used to cast metal specimens in a base metal alloy, Ticonium 100 (Ticonium Co., Albany, N.Y.). Manufacturer's directions were followed for investment, burn out, and casting. The sprued plastic squares (Fig.1) were invested by dipping the pattern into the paint-on Investic (Ticonium Co., Albany, N.Y.) investment mixed 50 grams to 15cc water. This paint-on layer allows for the escape of gases during casting. After setting, the painted-on pattern was dipped into water to wet the surface of the investment and placed into a Ticonium investment filled flask.

Burnout was accomplished using a Ticonium burnout oven from room temperature up to 1350 degrees F with a two hour heat soak at this temperature. A Ticomatic Auto Casting Machine (Ticonium Co., Albany, N.Y.) was used to cast the metal specimens. Two varieties of metal specimens were prepared; 40 for electrolytic etching and 40 with bead retention.

B. Electrolytic Etching

The specimens for electrolytic etching were recovered after casting, sandblasted, electropolished (Ti-Lectro, Ticonium Co., Albany, N.Y.) and faced with 400 grit silicone carbide abrasive. They were prepared according to the

Figure 1A

Horizontal view of sprued plastic patterns.

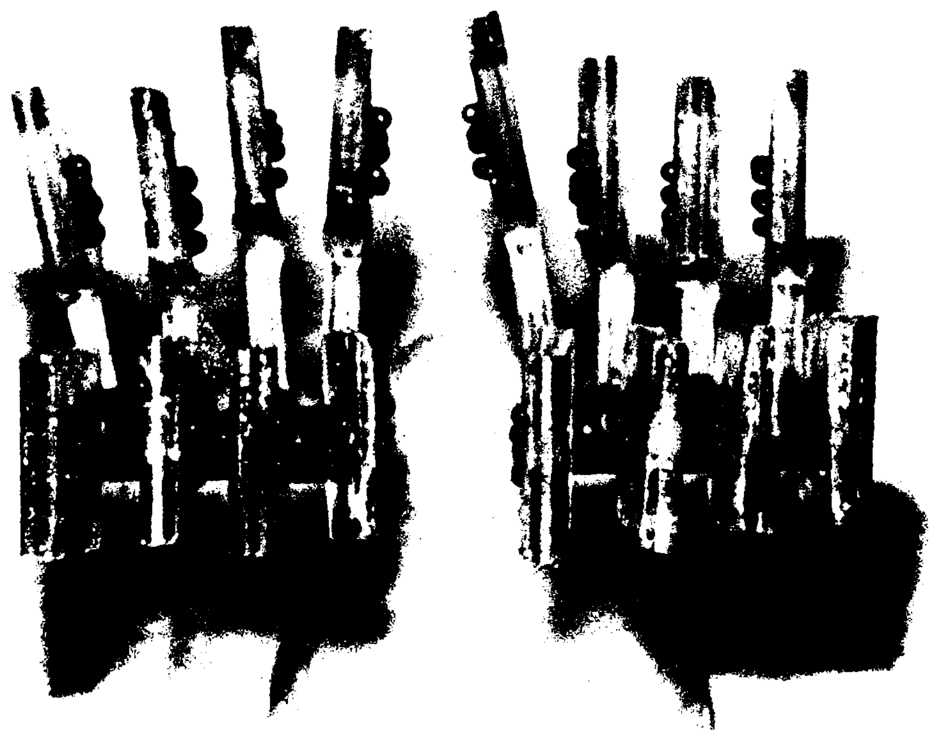


Figure 1B

Vertical view of plastic patterns prior to investing for casting.

manufacturer's directions for using the Time Etch etching machine by Dental Laboratories, Inc. (Baltimore, Md), (Fig 2). A 0.036 inch stainless steel wire electrode was attached to three metal specimens with sticky wax and tested for electrical current flow using the continuity tester on the Time Etch. Prior to etching, they were cleaned by air abrading with 50 micron aluminum oxide and then steam cleaned. Electrical continuity was again tested and the wire attached to the anode receptacle of the etcher with the metal specimens submerged in the acid. Another 0.036 inch stainless steel wire was attached to the cathode attachment of the Time Etch unit.

Electrolytic etching was performed using 10% sulfuric acid with a current density of 300 milliamps/cm sq. for three minutes. An 18% hydrochloric acid was used in an ultrasonic unit for 10 minutes to clean the metal surface after etching. They were then rinsed with distilled water. A stereo microscope at 50X was used to assure that uniform etching of the specimens had been achieved. Figure 3 shows a 50X scanning electron photomicrograph. Photomicrographs of representative specimens at different magnifications were made using the Phillips model 505 scanning electron microscope (Phillips Co., Houston, Tx.), (Fig 4).

C. **Bead Retention**

The bead retention specimens were prepared by overlaying the plastic patterns with 30 gauge sheet wax.

Figure 2

Time Etch etching machine by Dental Laboratories.

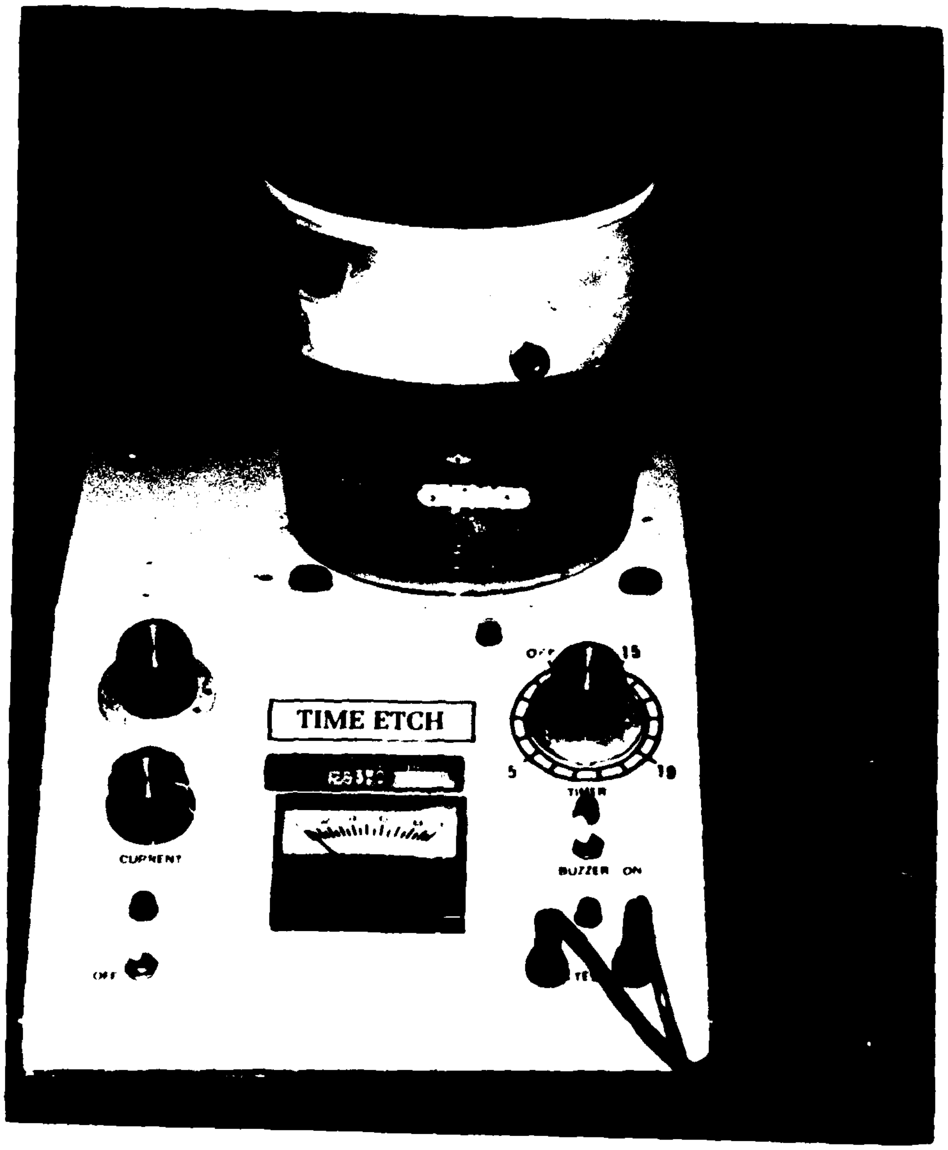

TIME ETCH
CURRENT
BUZZER ON
TIMER
OFF
15
5
10

Figure 3

Photomicrograph at 50X showing the etch representative for Ticonium.

Marker is one millimeter.

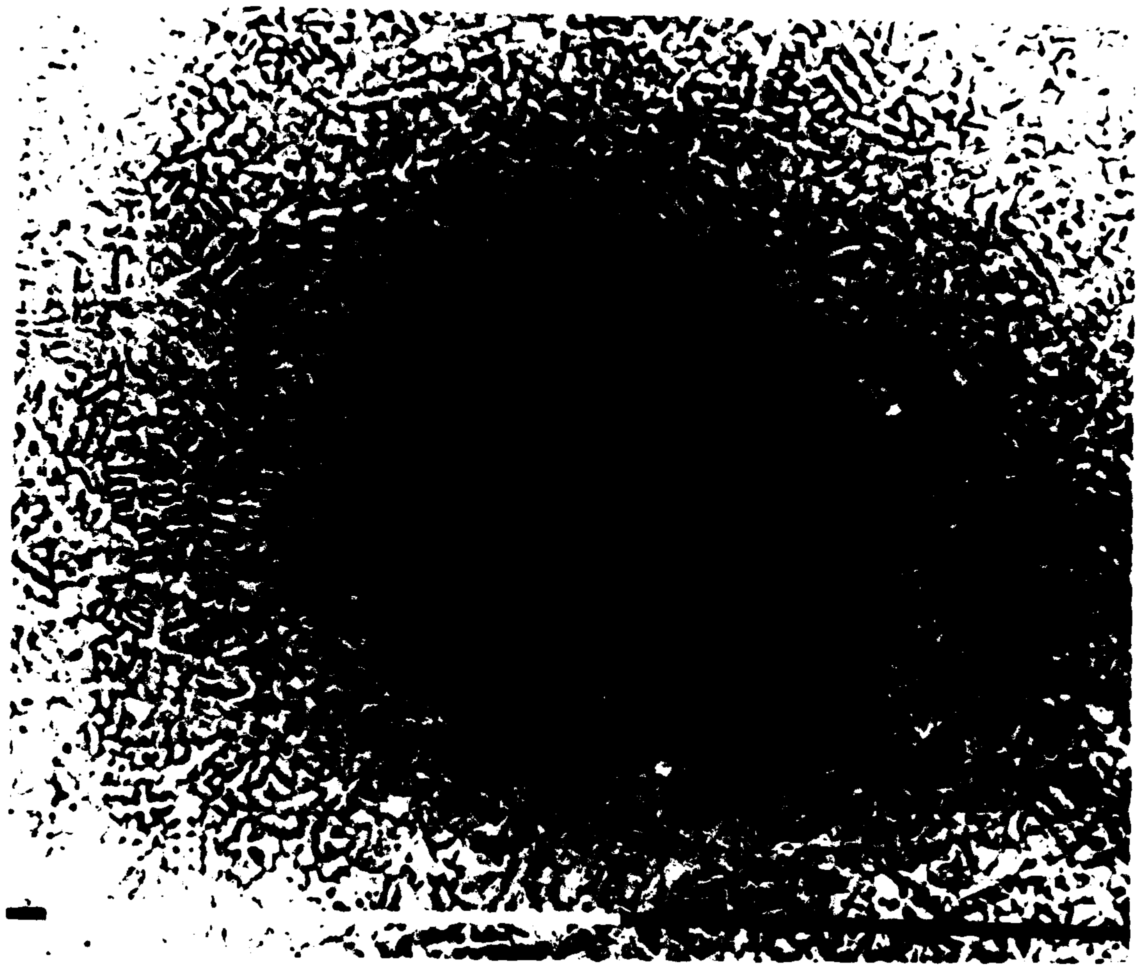


Figure 4A

Scanning photomicrograph of the etched metal surface at 200X. Marker is 0.1 millimeter.

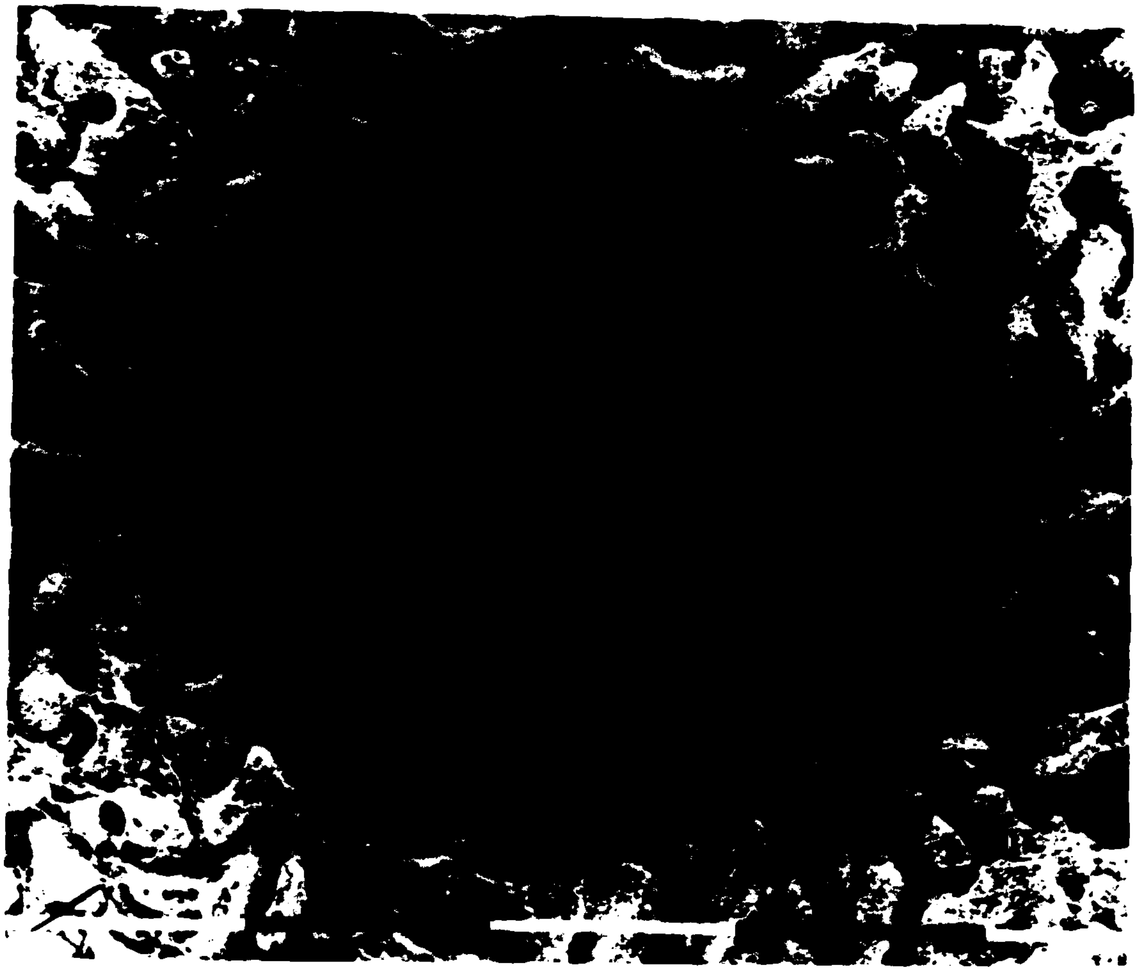
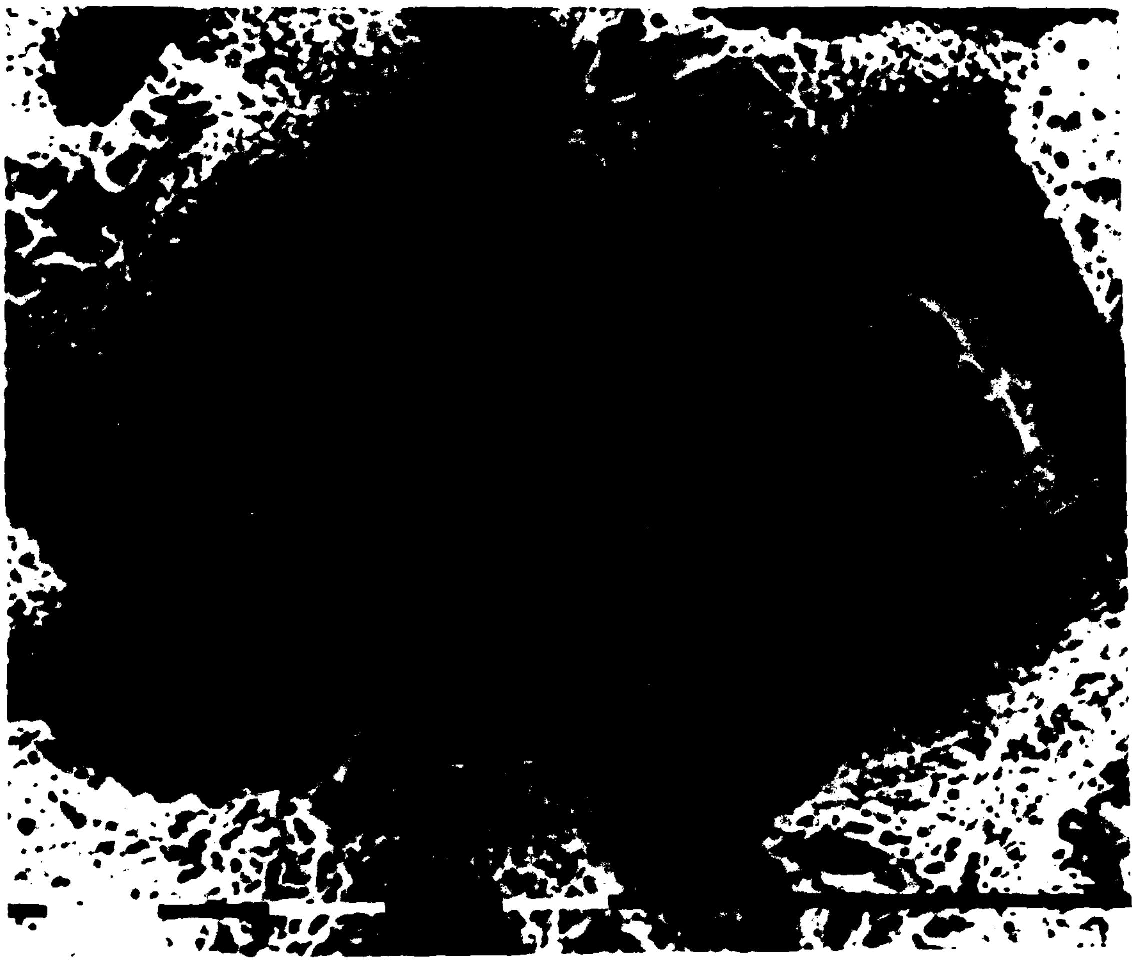


Figure 4B

Photomicrograph at 1000X of the etched
surface on the metal specimen.
Marker is 10 microns.



Six Kayon (Kay See Dental Manufacture Co., Kansas City, Mo.) synthetic resin retention beads size 14, approximately 1.0mm in diameter, were placed within a 5mm diameter circle in the center of the metal specimens. The beads were arranged so that the minimum space between any two beads was twice their diameter. Tacky liquid was painted on the 30 gauge wax and the beads lightly placed onto the wax using the wooden end of a cotton tip applicator. A representative retentive bead specimen is shown in Figure 5. The beads specimens were recovered after casting, sandblasted, and Ti-Lectro polished.

D. <u>Poly (Methyl Methacrylate) Processing</u>

To facilitate fabrication of a wax pattern for acrylic resin processing a teflon cylinder 3.5cm long was prepared with a 6.35mm diameter hole in the center (Fig 6). This cylinder was centered on the metal specimens and filled with melted baseplate wax (Hygenic Corp., Akaron, Ohio) using a glass eyedropper. To prevent premature solidification of the wax, the metal specimens were warmed on a glass slab over a water bath at 200 degrees F. Following sufficient cooling, the wax rod with the attached metal specimen was ejected from the teflon mold. Both the etched and the bead specimens were prepared for acrylic resin processing in this manner.

The specimens were flasked in a conventional upper denture flask (Hanau Engineering, Buffalo, N.Y.). The flask

Figure 5

Representative bead specimen showing the arrangement of the beads.

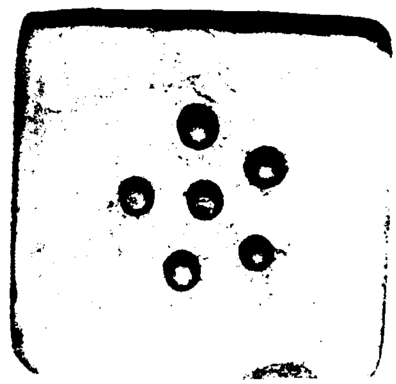
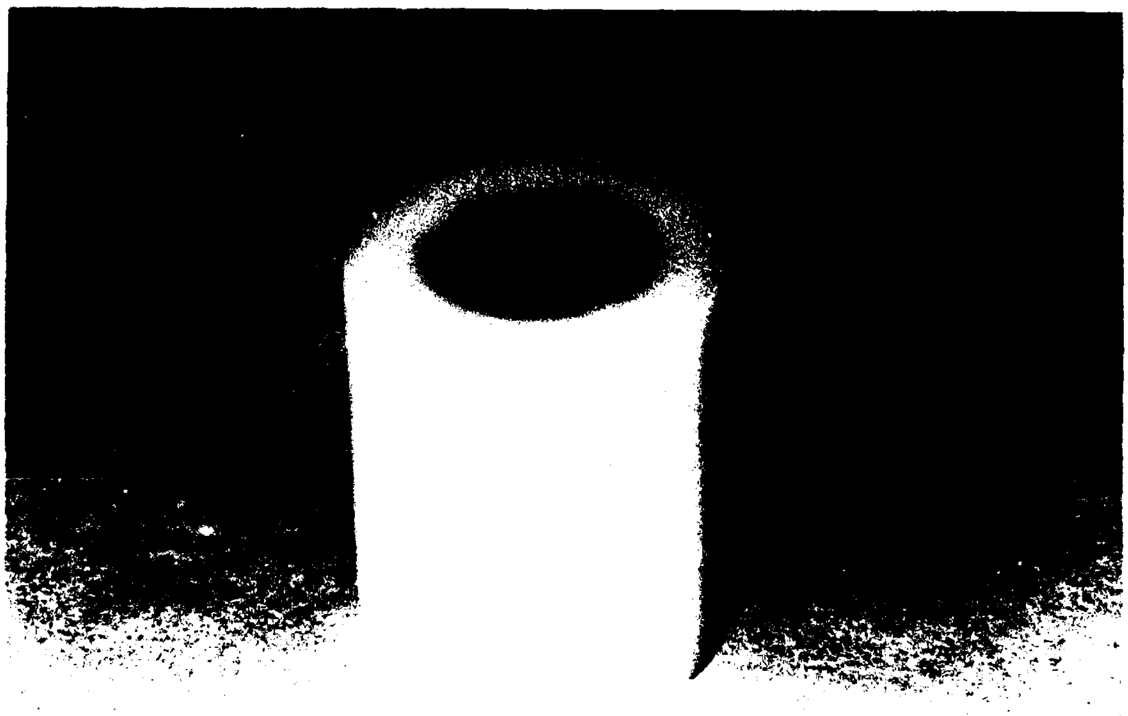


Figure 6A

Vertical view of the teflon cylinder used in the preparation of the wax patterns.

Figure 6B

Teflon cylinder with metal specimen centered in place.



was inverted and the metal specimen attached to the cap with a spot of sticky wax. Seven specimens were positioned around the periphery of the cap (Fig 7). The cope was placed on the cap and over the specimens. Dental stone was mixed and the cope filled so that the top of the wax rods were even with the top of the stone. Lastly, the drag was placed in position without the center plug and filled with dental stone to complete the modified flasking process.

After setting, the flasks were placed into boiling water. The wax was boiled out and wax solvent was used to remove any residue. Detergent was used to remove any oily film from the wax solvent and the flasks were allowed to cool. Alcote separating agent (L.D. Caulk Co., Milford, Dl.) was painted on the stone surfaces. Lucitone 199 (L.D. Caulk CO., Milford, Dl.) was mixed according to the manufacturer's directions. The specimens were packed similarly to dentures; three trial packs were done attaining 3000 psi pressure. The acrylic resin was cured for nine hours at 163 degrees F in a Hanau (Hanau Engineering, Buffalo, N.Y.) curing unit. The specimens were recovered, shell blasted, and stored in distilled water at 20 degrees C for 17 days prior to bond testing. Completed specimens are shown in Figure 8.

E. Tensile Strength Determination

Tensile bond strengths of the specimens were obtained using the Instron Universal Testing Machine (Instron Corp.,

Figure 7

Specimens positioned around the periphery of the cap for flasking.

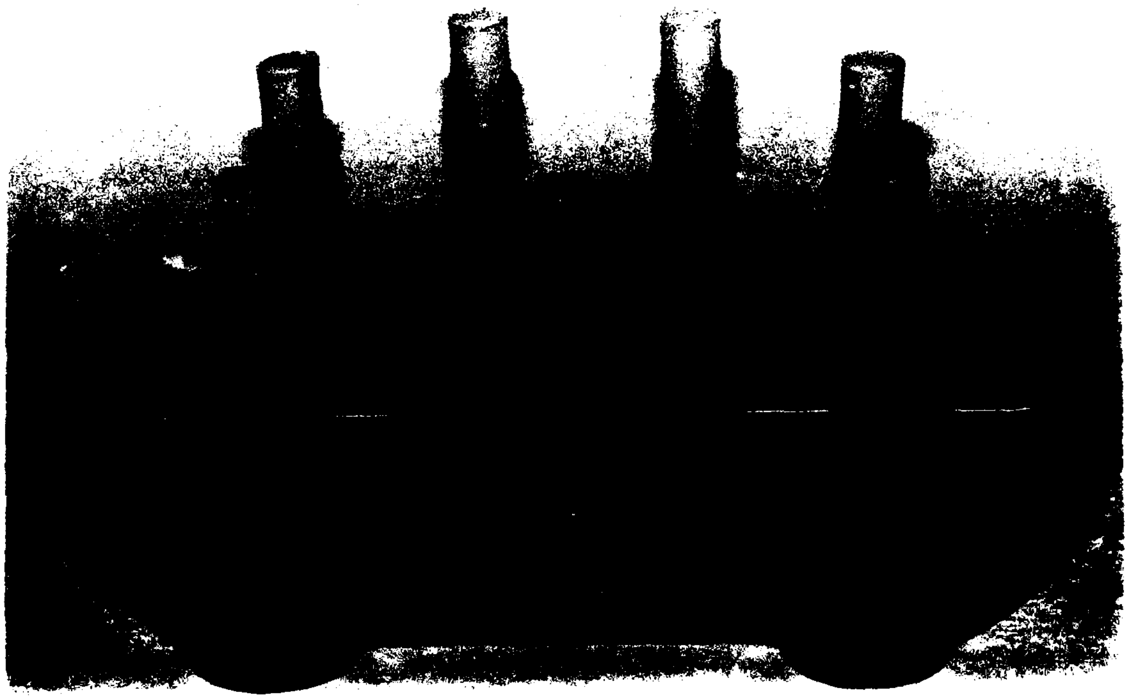
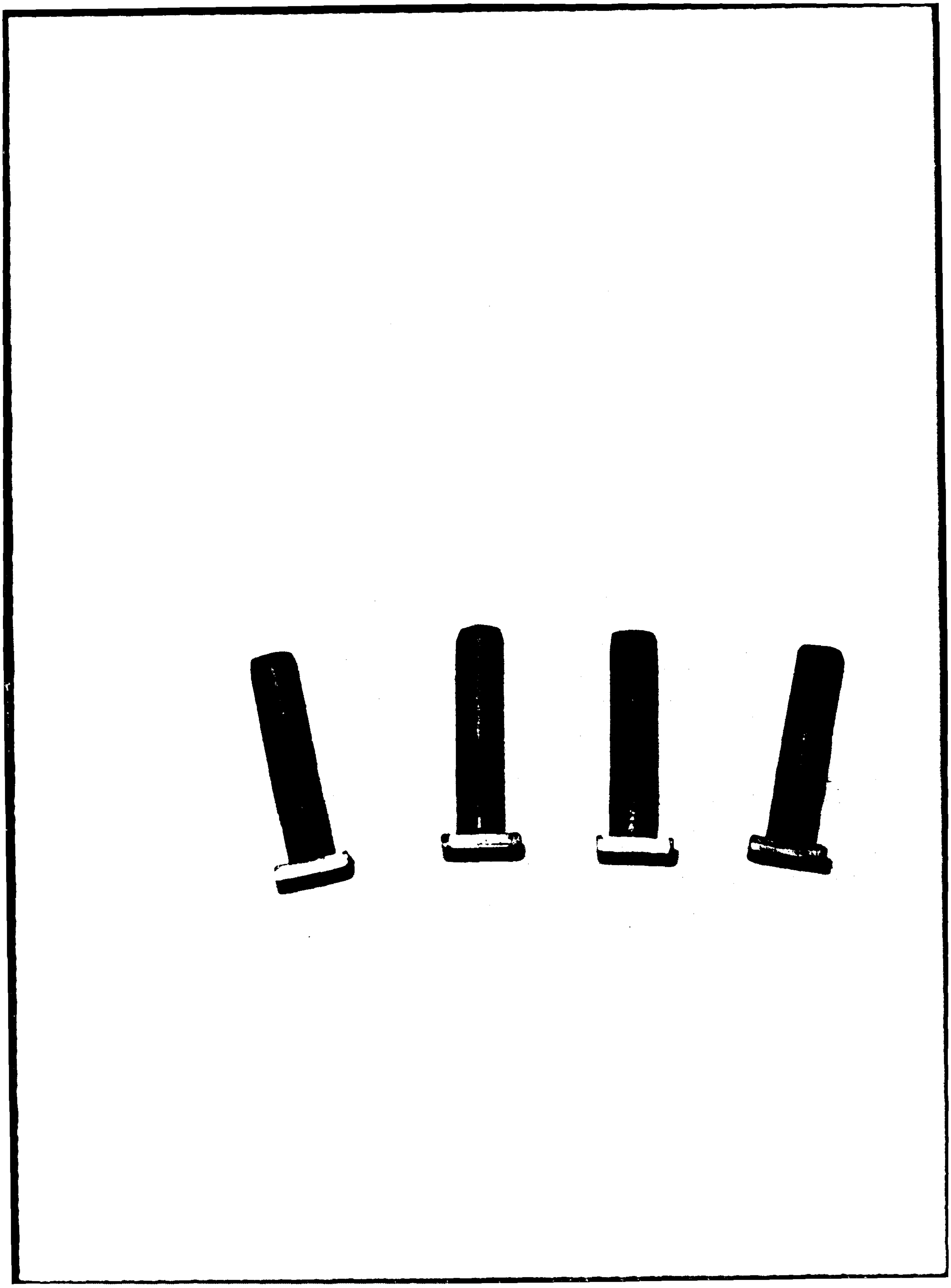


Figure 8.

Completed specimens ready for bond strength determination.



Canton, Mass.) with a 50 kilonewton load cell. The metal tabs were positioned in a holding device on the upper arm of the Instron, and self aligning "V"-grips were used to grasp the acrylic resin rod from the lower arm (Fig 9).

The chart paper speed was set at 50mm/min. Full scale load was 1000 newtons. The crosshead speed for the Instron was set at 5mm/min. The force in newtons required to separate the acrylic resin rods from the metal specimens was recorded as the tensile bond strength.

F. Shear Strength Determination

Shear bond strengths of the specimens were determined in the following manner. The metal specimens were stabilized in a device which allowed loading of the acrylic resin rods perpendicularly to their long axis. An upper shearing blade was placed flush against the metal surface and the specimens were loaded with a crosshead speed of 5mm/min (Fig 10). The force in Newtons required to separate the acrylic resin rod from the metal specimen was recorded as the shear bond strength.

G. Evaluation Of Fracture Site

A Scanning Electron Microscope was used to evaluate the fracture site of representative etched and the bead specimens. Specimens to be examined were mounted on standard SEM mounts with double-sided tape and conduction established with silver paint (Fig 11). The specimens were

Figure 9A

Specimen in the upper holding device of the Instron Machine.

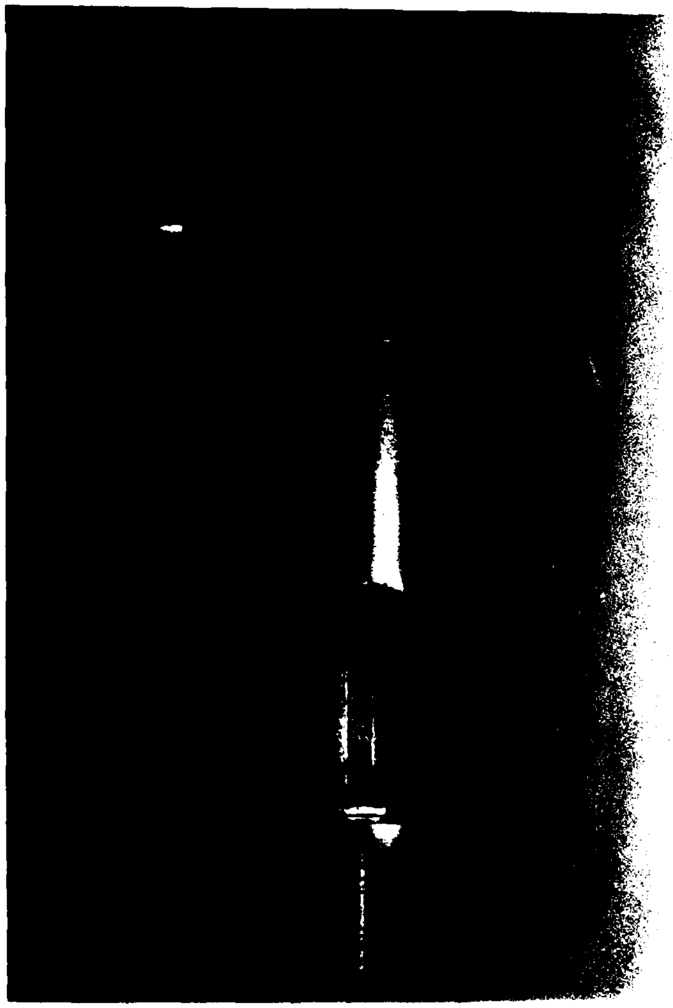


Figure 9B

Specimen in place for tensile bond evaluation. Self-aligning "V"-grips are holding the acrylic resin rod.

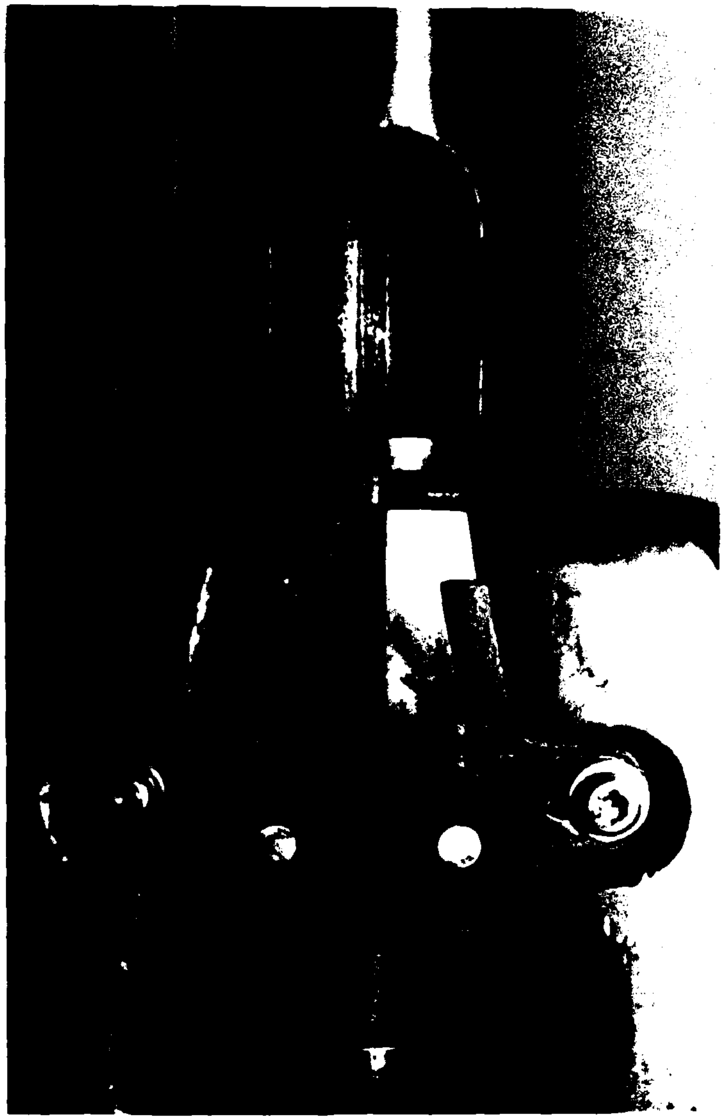


Figure 10A

Specimen positioned in holding device for shear bond evaluation with shearing blade.

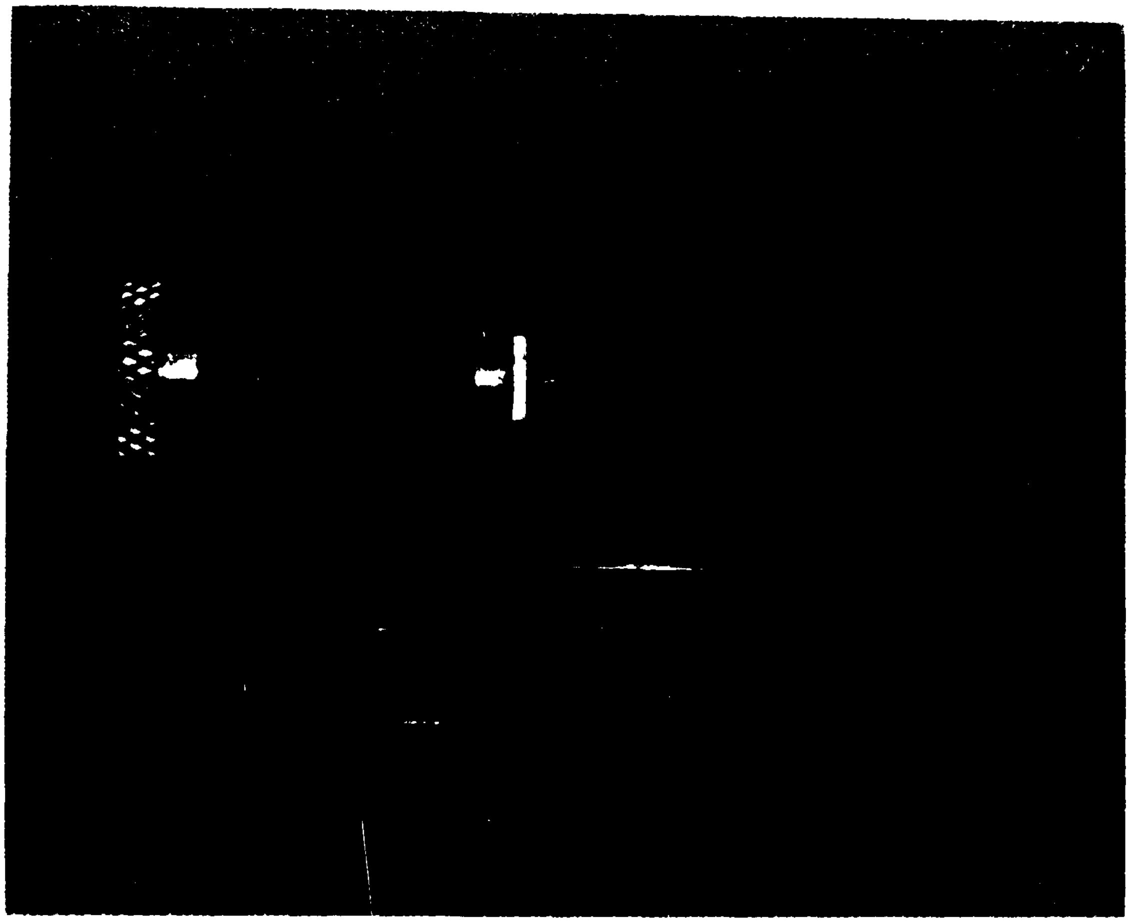


Figure 10B

Specimen in the Instron Machine ready for shear bond determination.

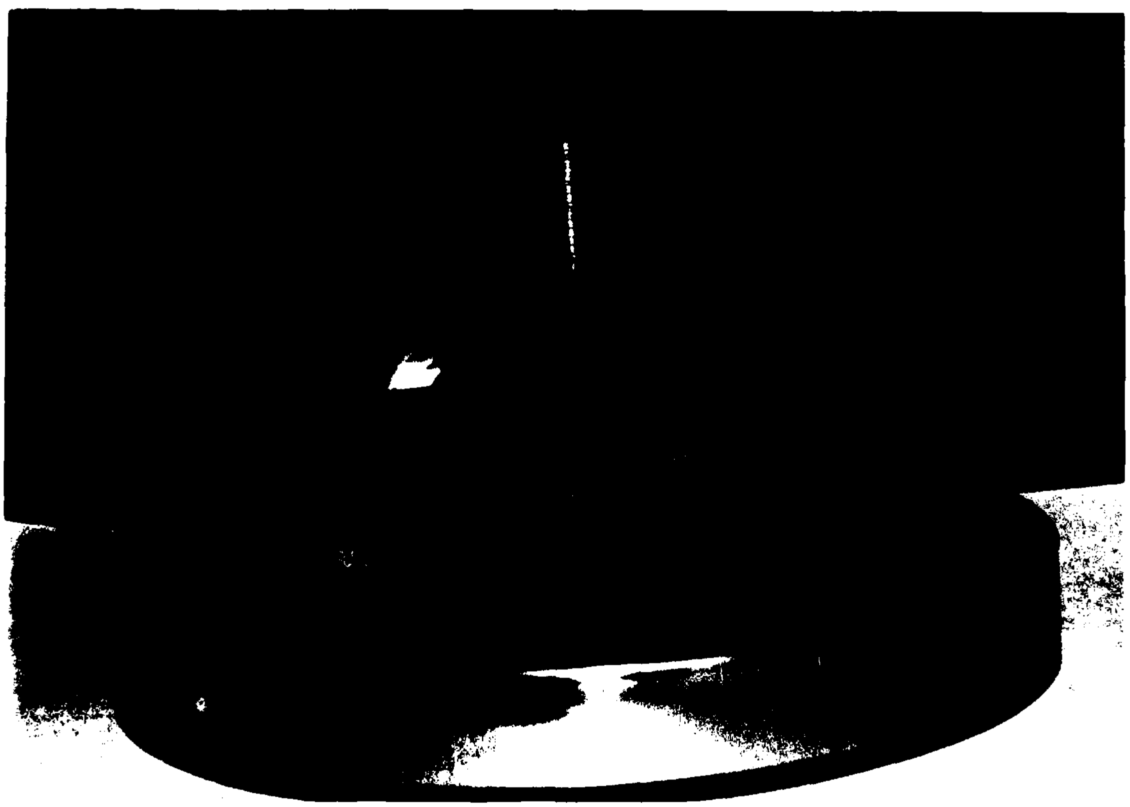
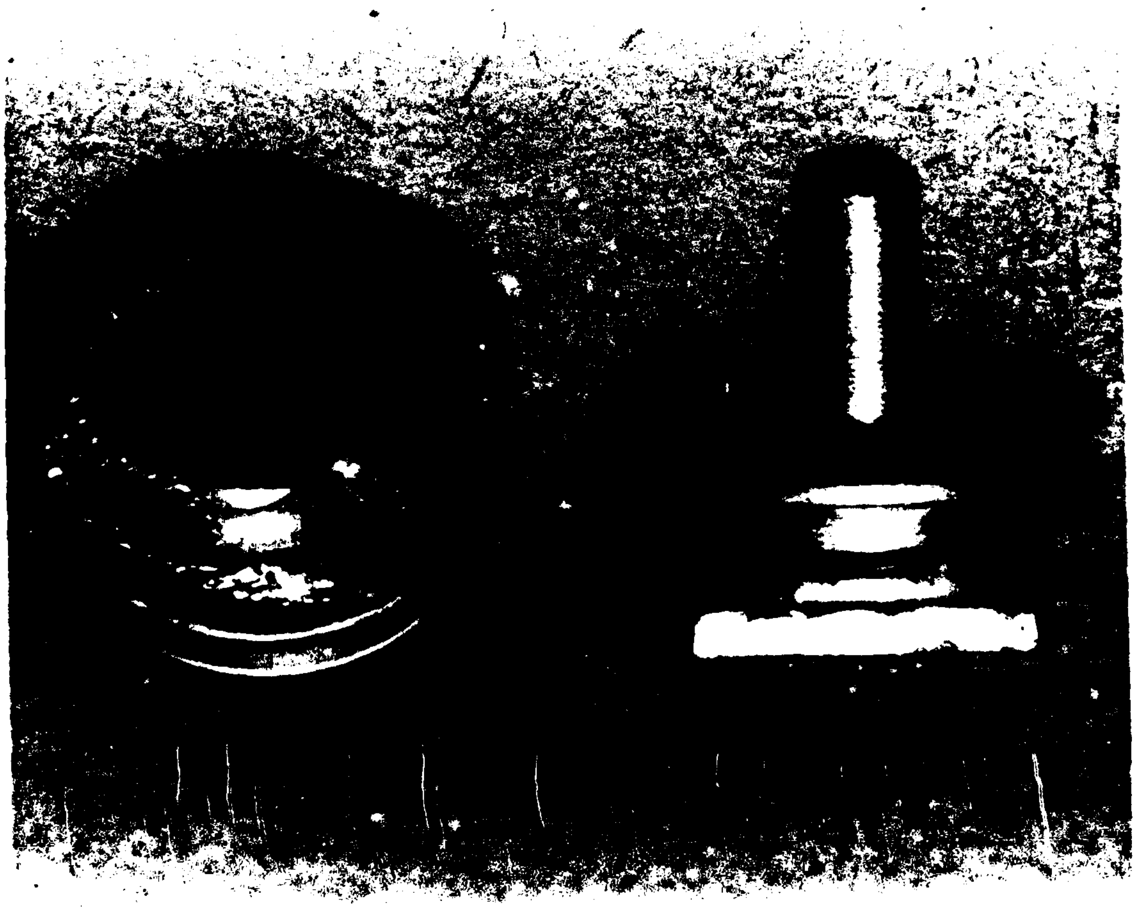


Figure 11

Specimens mounted for examination in the scanning electron microscope.



sputter coated (Hummer Model 10) for four minutes using a target of gold and palladium. Representative specimens with mean strength values for the two retentive techniques were examined with a scanning electron microscope and evaluated as to their fracture mode.

H. Evaluation Of Results

The resulting tensile and shear bond strengths were subjected to a Students' T-test to determine if significant differences in bond strengths were observed.

V. RESULTS

The results of the tensile bond strengths for the etched and the bead specimens are shown in Table 1. The mean tensile bond strength for the etched specimens was 472.5 newtons (16.70 MPa) with a standard deviation of 130.1 newtons (4.60MPa). The mean tensile bond strength for the bead specimens was 134.9 newtons (4.77 MPa) with a standard deviation of 75.7 newtons (2.68 MPa).

Statistical anaylsis using the Students' T-test revealed that the tensile etched bond strengths were significantly ($p < 0.001$) greater than the tensile bead strengths.

Examination of the fracture sites of the tensile specimens using the scanning electron microscope demonstrated that a predominantly cohesive failure occurred within the poly (methyl methacrylate) at the etched surface of the Ticonium. Acrylic resin fragments were found to be mechanically locked into the etched metal specimens (Fig 12 and Fig 13), and metal particles were observed imbedded in the fractured acrylic resin surfaces. Examination of the bead specimens showed that an adhesive failure occurred between the acrylic resin and the beads (Fig 14).

The results of the shear bond strengths for the etched and the bead specimens are shown in Table 2. The mean shear bond strength for the etched specimens was 345.7 newtons

TABLE 1

Tensile Bond Strengths For The Etched And Bead Specimens

Etched Samples number	Etched Samples newtons	Bead Samples number	Bead Samples newtons
3	610	1	53
4	357	2	240
5	341	6	250
7	665	10	189
8	533	11	95
9	567	12	47
18	515	13	83
21	585	14	25
22	577	15	249
23	506	16	80
24	143	17	130
26	300	19	220
27	308	20	137
28	440	25	199
29	432	31	83
30	513	32	235
33	500	35	82
34	512	37	47
36	620	38	97
40	426	39	177

	Etched Samples		Bead Samples
RANGE:	143 - 665	RANGE:	25 - 250
MEAN:	472.5 newtons 16.70 MPa	MEAN:	134.9 newtons 4.77 MPa
STD DEV:	130.1 newtons 4.60 MPa	STD DEV:	75.7 newtons 2.68 MPa

T VAL: 10.03

D F: 38

P VAL: < 0.001

Figure 12

Cohesive failure of the acrylic resin with the etched metal specimen at 50x.

Marker is one millimeter.

Figure 13

Acrylic resin retained in the etch. Note difference (arrow) between the area of acrylic resin attachment and the surrounding etched metal surface, 45X. Marker is one millimeter.

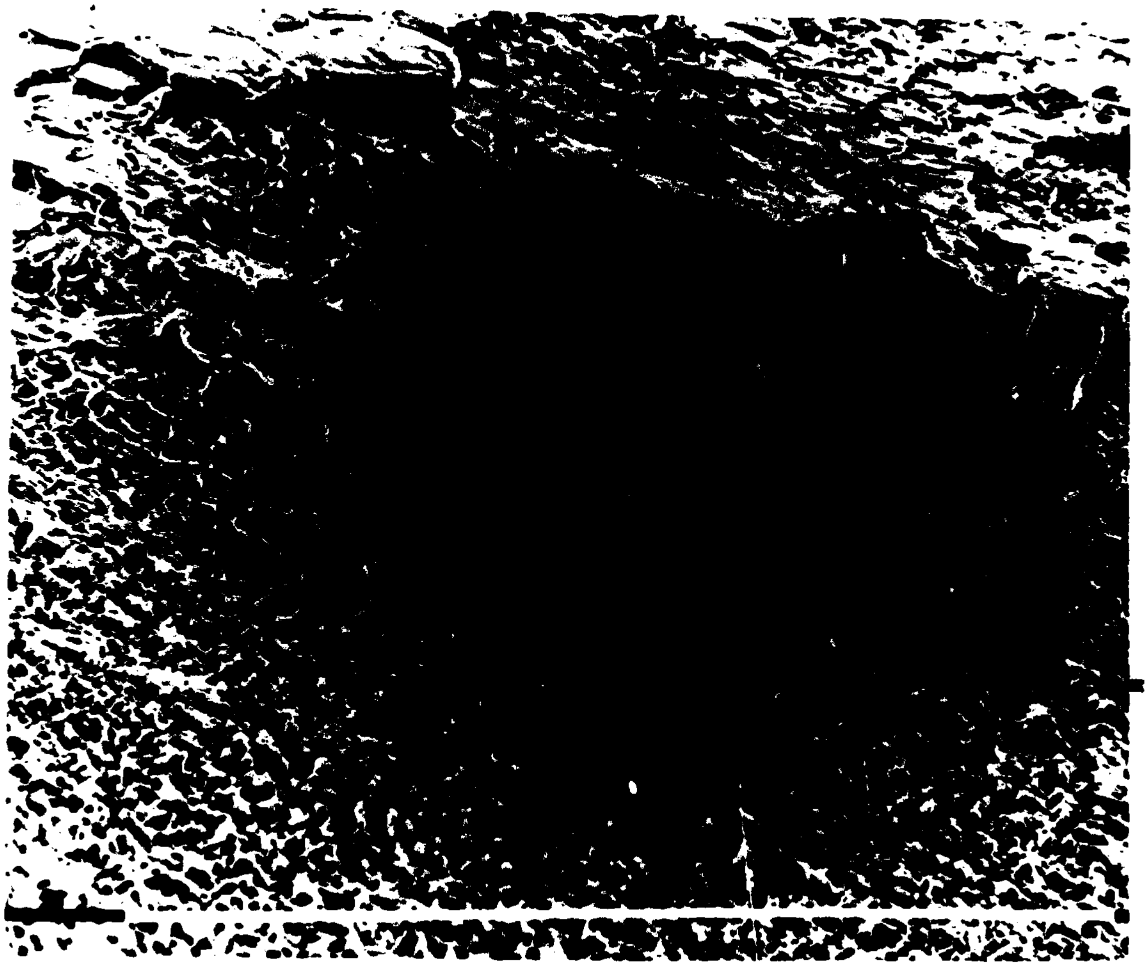


Figure 14A

Adhesive failure and plastic deformation of the acrylic resin on beads at 20X.
Marker is one millimeter.

AD-A172 150 THE TENSILE AND SHEAR BOND STRENGTHS OFPPOLY (METHYL 2/2
METHACRYLATE) PROCES. (U) AIR FORCE INST OF TECH
WRIGHT-PATTERSON AFB OH J E ZURASKY MAY 86

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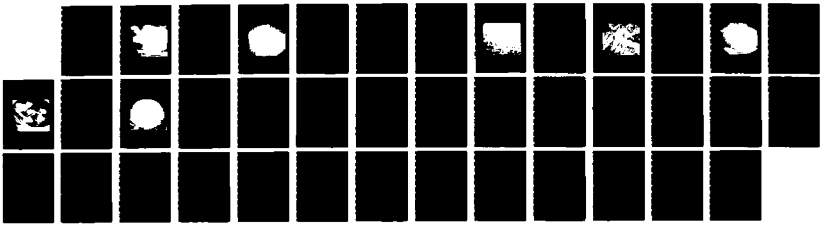
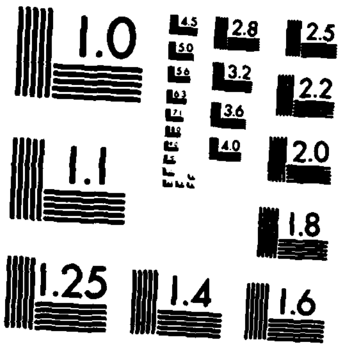




MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Figure 14B

Adhesive failure of the acrylic resin on beads at 20X. Marker is one millimeter.

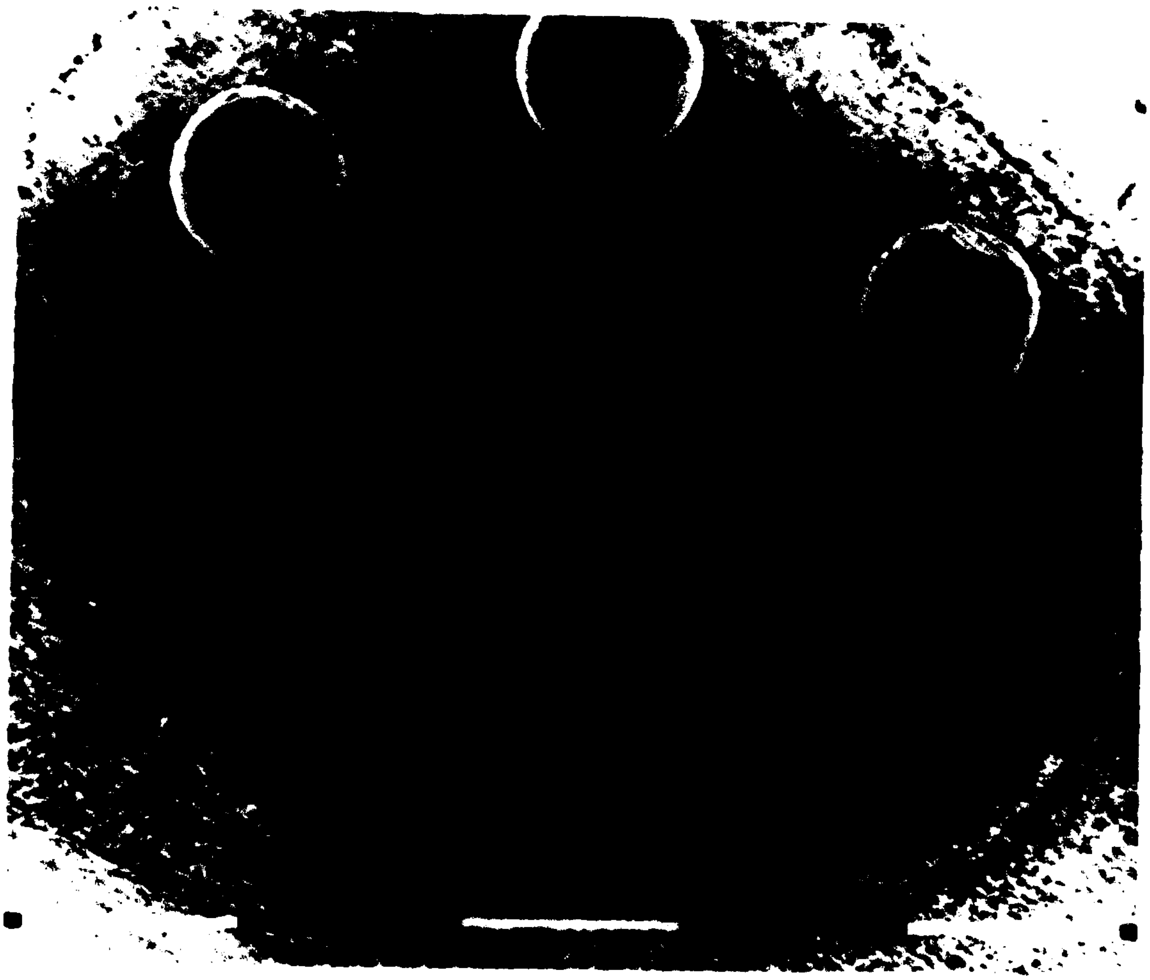


TABLE 2

Shear Bond Strengths For The Etched And Bead Specimens

Etched Samples number	Etched Samples newtons	Bead Samples number	Bead Samples newtons
101	199	104	403
102	223	105	480
103	225	106	428
107	380	108	588
109	413	111	560
110	399	112	562
113	340	117	511
114	365	118	571
115	309	119	450
116	368	122	506
120	275	124	600
121	431	125	335
123	239	126	467
127	390	128	508
129	375	130	552
133	424	131	565
134	381	132	647
135	298	136	403
139	459	137	480
140	302	138	556

	Etched Samples		Bead Samples
RANGE:	199 - 459	RANGE:	335 - 647
MEAN:	345.7 newtons 12.22 MPa	MEAN:	508.6 newtons 17.97 MPa
STD DEV:	71.1 newtons 2.51 MPa	STD DEV:	71.1 newtons 2.51 MPa
T VAL:	-6.89		
D F:	38		
P VAL:	<0.001		

(12.22 MPa) with a standard deviation of 71.1 newtons (2.51MPa). The mean shear bond strength for the bead specimens was 508.6 newtons (17.97 MPa) with a standard deviation of 71.1 newtons (2.51 MPa).

Although a Students' T-test on this data resulted in a significantly higher bond strength for the bead specimens these results are in question due to complications during the shear bond testing.

Examination of the fracture sites using the scanning electron microscope once again demonstrated cohesive failure within the poly (methyl methacrylate) at the etched surface. Acrylic resin fragments remained mechanically locked to the micro-retention of the etching (Fig 15). Extensive plastic deformation of the poly (methyl methacrylate) was evident during examination of the fractured acrylic resin (Fig 16).

The shear fractured bead specimens again showed an adhesive failure between the metal and the acrylic resin with even more extensive plastic deformation of the poly (methyl methacrylate) due to the shearing blade (Fig 17). Some of the beads were sheared off by contact with the blade as it cut into the acrylic resin (Fig 18).

Figure 15A

Acrylic resin adhering to the etched metal surface after shear failure, 250X. Marker is 0.1 millimeter.

Figure 15B

Cohesive shear failure of the acrylic resin on an etched specimen at 2000X.
Marker is 10 microns.

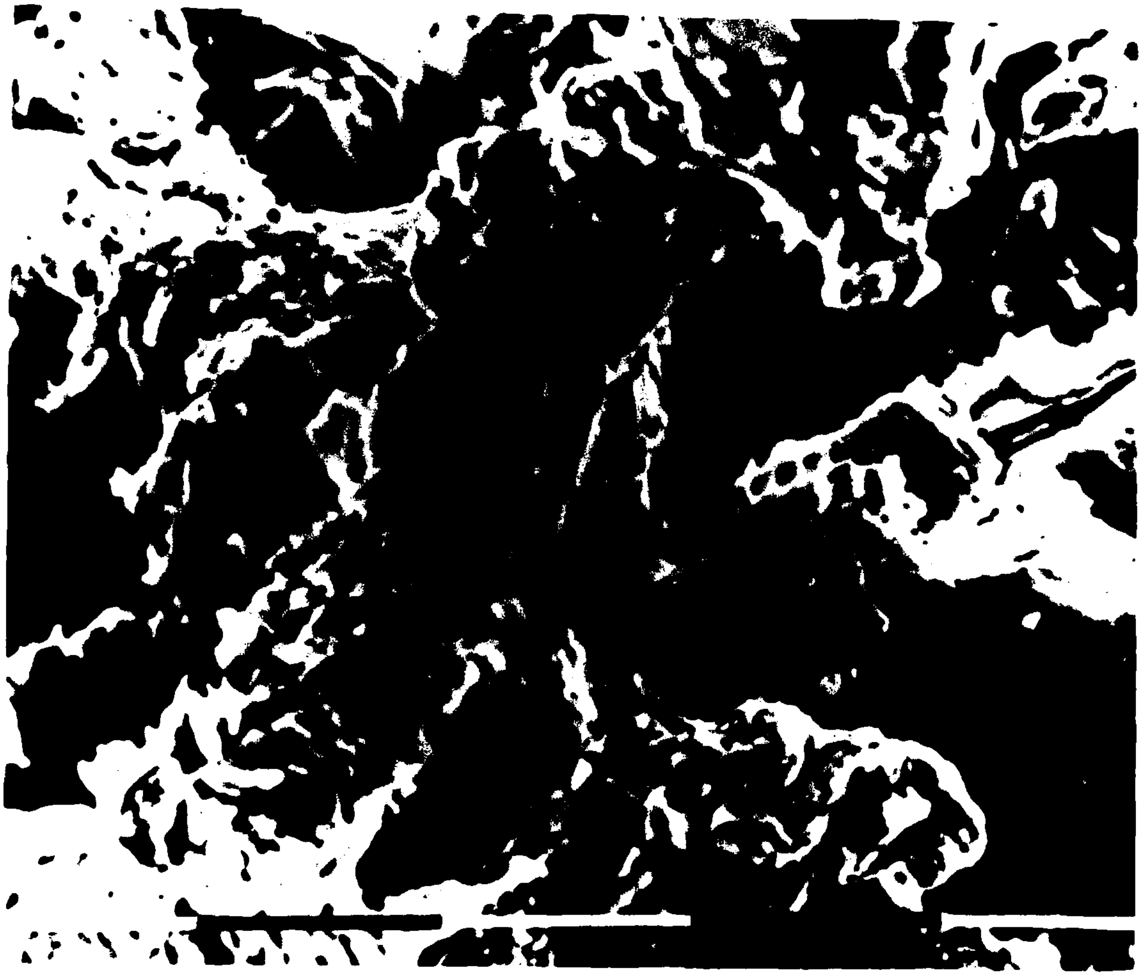


Figure 16

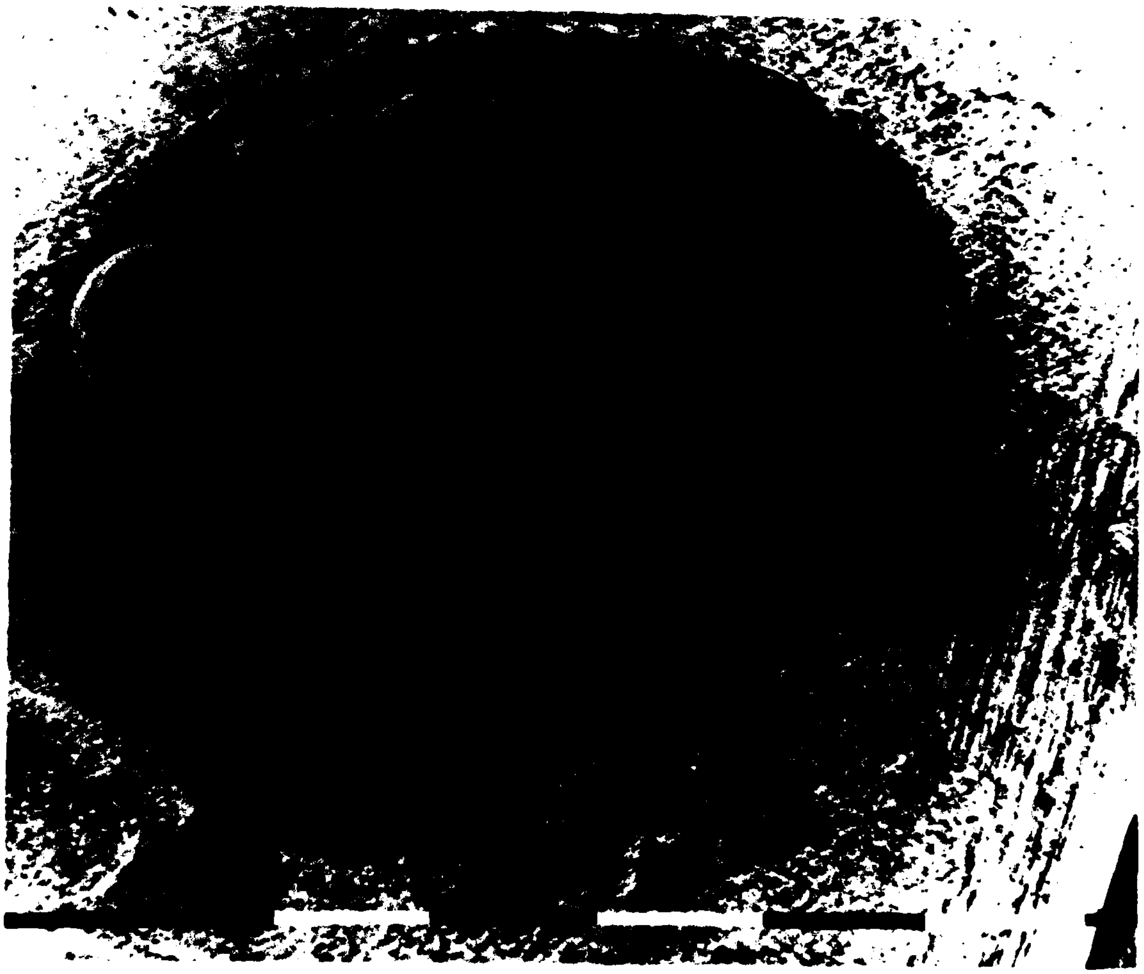
Surface of the acrylic resin rod after shear failure from the etched surface at 20X. Marker is one millimeter.

Figure 17

Severe plastic deformation of the acrylic resin sheared from a bead specimen at 20X. Note the deformation due to the shearing blade. Marker is one millimeter.

Figure 18

Metal bead specimen with the loss of two beads due to contact with the shearing blade, 15X. Marker is one millimeter.



VI. DISCUSSION

Fabrication and preparation of the test specimens were accomplished with laboratory methods that are commonly used for clinical prostheses. These same laboratory procedures would be used for clinical application of the results of this research.

The poly (methyl methacrylate) rod was waxed-up directly on the etched surface of the metal. The waxed metal was flasked in a denture flask and the wax boiled out in the boiling tank. Wax solvent was used on the etching to dissolve any remaining wax and then detergent was used to remove any oily residue.

The etched surface was fully contaminated with these materials, and then flushed with clean boiling water, and allowed to dry before the acrylic resin was split-packed.

The effect of any manipulation or contamination of the etched metal surface has not been studied in depth. It has been reported by McLaughlin (1981, 1982) and Thompson and Livaditis (1982) that the etched surface of the metal must be maintained contamination-free to preserve the bonding capability. This research indicates that manipulation and contamination may not be as critical as was originally thought. Some consideration must be given to the packing conditions of 3000 psi applied pressure which cannot be directly compared to composite resins placed intraorally.

Meiers et al.(1985) looked at a variety of surface treatments on the bond strength of etched metal retainers. They found that abrasion with salivary contamination did not ecrease the shear bond strength, and that the etched metal surface may not be as fragile as was thought. It is evident that further research is necessary in this area.

Controlling the etching conditions is one of the most important factors in consistent etching. Metal etching is the result of dissolution of the more corrodible elements in the metal by the action of the acid in relation to current and time. The etching occurs at a predictable rate and can be controlled with attention to all details involved. Using controlled times and currents with precisely measured acids a 50-70 micron deep retentive etch can be obtained. The etch should be verified using a stereo microscope in the 40-60 power range. Interdendritic attack specific for the metal etched can be seen. This uniform dendritic pattern is not the sole retentive feature but is indicative of its presence. The micro-retentive undercuts are apparent under higher magnification.

The results of the tensile bond test show that microscopic retention of the poly (methyl methacrylate) is much more desirable than the accepted bead retention. The etched tensile bond is nearly 3.5 times the strength of the bond with beads. The etched bond is available over the entire surface area in contrast to the limited retention around the beads. It is probable that due to this increased

surface area of bonding there would be less metal-resin interface percolation, staining, and odor.

These findings show that a very strong mechanical bond is achievable between the etched metal base or removable partial denture framework and the acrylic resin.

The results of the shear bond test show that although shear testing is used frequently to evaluate the etched-composite resin bond, this test is not appropriate for quantifying the shear strength of poly (methyl methacrylate) on beads. The shear test on the bead specimens initiated extensive plastic deformation of the acrylic resin allowing the shearing blade to penetrate into the acrylic resin contacting the metal beads. The resulting bond strengths are not a true representation of the actual bond.

VII. SUMMARY

This research examines the microscopic mechanical bonding of acrylic resin to electrolytically etched base metal alloy by comparing the etched tensile and shear bond strengths to the clinically accepted macroscopic mechanical bond of acrylic resin to beads.

Tensile and shear bond strengths were quanitatively measured on an Instron Universal Testing Machine and a Scanning Electron Microscope was used to evaluate the fracture sites.

The shear bond test for acrylic resin on beads was found to be inappropriate. Excessive plastic deformation of the acrylic resin allowed the shearing blade to penetrate into the acrylic resin contacting the metal beads and distorting the shear bond values. This does not significantly affect the results or the conclusions of this research due to the fact that clinical problems have been reported to relate directly to tensile failures.

Table 3 is a summary of the tensile bond strengths comparing the two systems. The tensile bond strength using electrolytic etching to obtain microscopic retention of poly (methyl methacrylate) on base metal alloy is much higher than the accepted bead retention.

The following conclusions and recommendations can be made from the results of this research:

1. The etched tensile bond is nearly 3.5 times the

Table 3

SUMMARY

TENSILE BOND STRENGTHS OF ETCHED AND BEAD SPECIMENS

Technique	N	Mean bond	S.D.
Etched	20	16.70 MPa	4.60 MPa
Beads	20	4.77 MPa	2.68 MPa

$P < 0.001$

strength of the tensile bond with beads.

2. The tensile and shear fractures for the etched specimens were a cohesive failure in the acrylic resin.

3. The tensile and shear fractures for the bead specimens were total adhesive failures at the acrylic resin-metal interface.

4. Protecting the etched surface against contamination is not critical during the laboratory processing of poly (methyl methacrylate) onto the etched surface.

5. The clinical applicability of this research can be used on a base metal prosthesis where retention of acrylic resin is necessary. This retention capability can salvage an ill-fitting metal based denture by allowing a reline of the intaglio surface. The acrylic resin will bond to the metal over the entire etched surface area. Acrylic resin retention has always been a problem where interarch space is minimal. Microscopic etched retention preserves the maximum remaining space for placement of artifical teeth.

6. Further research is indicated on this topic. One area is the probable reduction of percolation, staining, and odor at the acrylic resin-metal interface enhancing the acceptability of the prosthesis. Another area is the masking of the etched metal when only a thin layer of acrylic resin is to cover the metal.

APPENDICIES

APPENDIX A

Raw Data Tensile Bond Strengths

Specimen #	Type	Bond Strength (Newtons)
1	Bead	53
2	Bead	240
3	Etch	610
4	Etch	357
5	Etch	341
6	Bead	250
7	Etch	665
8	Etch	533
9	Etch	567
10	Bead	189
11	Bead	95
12	Bead	47
13	Bead	83
14	Bead	25
15	Bead	249
16	Bead	80
17	Bead	130
18	Etch	515
19	Bead	220
20	Bead	137
21	Etch	585
22	Etch	577
23	Etch	506

Raw Data Tensile Bond Strengths Continued

Specimen #	Type	Bond Strength (Newtons)
24	Etch	143
25	Bead	199
26	Etch	300
27	Etch	308
28	Etch	440
29	Etch	432
30	Etch	513
31	Bead	83
32	Bead	235
33	Etch	500
34	Etch	512
35	Bead	82
36	Etch	620
37	Bead	47
38	Bead	97
39	Bead	177
40	Etch	426

APPENDIX B

Raw Data Shear Bond Strengths

Specimen #	Type	Bond Strength(Newtons)
101	Etch	199
102	Etch	223
103	Etch	225
104	Bead	403
105	Bead	480
106	Bead	428
107	Etch	380
108	Bead	588
109	Etch	413
110	Etch	399
111	Bead	560
112	Bead	562
113	Etch	340
114	Etch	365
115	Etch	309
116	Etch	368
117	Bead	511
118	Bead	571
119	Bead	450
120	Etch	275
121	Etch	431
122	Bead	506
123	Etch	299
124	Bead	600

Raw Data Shear Bond Strengths Continued

Specimen #	Type	Bond Strength (Newton)
125	Bead	335
126	Bead	467
127	Etch	390
128	Bead	508
129	Etch	357
130	Bead	552
131	Bead	565
133	Etch	424
134	Etch	381
135	Etch	298
136	Bead	403
137	Bead	480
138	Bead	556
139	Etch	459
140	Etch	302

APPENDIX C

Manufacturers and Materials

1. Alcote - L.D. Caulk Company, Milford, Delaware.
2. Hanau Curing Unit - Hanau Engineering, Buffalo, New York.
3. Hanau Denture Flask - Hanau Engineering, Buffalo, New York.
4. Hygenic Baseplate Wax - Hygenic Corporation, Akaron, Ohio.
5. Instron Universal Testing Machine - Instron Corporation, Canton, Massachusetts.
6. Investic - Ticonium Corporation, Albany, New York.
7. Kayon Beads - Kay See Dental Manufacture Company, Kanas City, Missouri.
8. Lucitone 199 - L.D. Caulk Company, Milford, Delaware.
9. Phillips Model 505 Scanning Electron Microscope - Phillips Company, Houston, Texas.
10. Ticomatic Auto Casting Machine - Ticonium Corporation, Albany, New York.
11. Ticonium 100 - Ticonium Company, Albany, New York.
12. Ti-Lectro Polisher - Ticonium Corporation, Albany, New York.
13. Time Etch - Dental Laboratories, Inc., Baltimore, Maryland.

APPENDIX D

Technical References

1. Time Etch - Dental Laboratories, Inc., Baltimore, Maryland.
2. Ticonium Technique Manual - Ticonium Company, CMP Industries, Albany, New York.
3. Instron Operating Manual - Instron Corporation, Canton, Massachusetts.

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John E. Zurasky was born on the tenth of September, 1950, in New Castle, Pennsylvania. He graduated from Shenango High School in May of 1968, and began his undergraduate education at Youngstown State University, Youngstown, Ohio, that year. He graduated with a Bachelor of Science degree in Biology in March, 1973.

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